

AMENDMENTS
TO
THE WATER QUALITY CONTROL PLAN FOR THE
SACRAMENTO RIVER AND SAN JOAQUIN RIVER
BASINS

FOR
THE CONTROL OF ORCHARD PESTICIDE RUNOFF AND
DIAZINON RUNOFF INTO THE SACRAMENTO AND
FEATHER RIVERS

FINAL STAFF REPORT

Appendices

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APPENDIX A

TOTAL MAXIMUM DAILY LOAD CALCULATIONS

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List of Acronyms and Abbreviations

§	Section (as in a law or regulation)
Σ	Sum
µg/L	Micrograms/liter
a.i.	Active ingredient of a pesticide
Basin Plan	Water Quality Control Plan (Basin Plan) Central Valley Region ; Sacramento River and San Joaquin River Basins
CCC	Criterion Continuous Concentration
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDPR	California Department of Pesticide Regulation
CMC	Criterion Maximum Concentration
CRWQCB-CVR	California Valley Regional Water Quality Control Board - Central Valley Region
CWA	Federal Clean Water Act
CWC	California Water Code
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
ELISA	Enzyme-linked immunosorbent assays
Exceedance or Excursion	Used to refer to a data point above a criteria value
in.	Inches
LA	Load allocation
Lbs	pounds
LC	Loading capacity
LOQ	Limit of quantification
MOS	Margin of safety
Natomas Cross Canal	A canal in Sacramento County, also sometimes referred to as the Cross Canal
ng/L	Nanograms/liter
NWIS	National Water Information System
Porter-Cologne or Porter-Cologne Act	Porter-Cologne Water Quality Control Act as amended
Ppm	Parts per million
PUR	Pesticide Use Report
State Board or SWRCB	California State Water Resources Control Board

List of Acronyms and Abbreviations

SWDB	Surface Water Database
TIE	Toxicity Identification Evaluation
TMDL	Total Maximum Daily Load
UCIPM	University of California Statewide Integrated Pest Management Project
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation

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A.1 Introduction

A.1.1 Regulatory Background

A.1.1.1 Clean Water Act Section 303(d)

Section 303(d) of the federal Clean Water Act (CWA) requires States to: 1) identify those waters not attaining water quality standards (referred to as the “303(d) list”); 2) set priorities for addressing the identified pollution problems; and 3) establish a “Total Maximum Daily Load” (TMDL) for each identified waterbody and pollutant to attain water quality standards. The 303(d) list for the Central Valley is prepared by the California Regional Water Quality Control Board, Central Valley Region (Regional Board) and approved by the State Water Resources Control Board (State Board) and the United States Environmental Protection Agency (US EPA).

Waterbodies on the 303(d) list are not expected to meet water quality standards even if dischargers of point sources comply with their current discharge permit requirements. A TMDL represents the maximum load (usually expressed as a rate, such as grams/day [g/day]) of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL describes the reductions needed to meet water quality standards and allocates those reductions among the sources in the watershed. A TMDL is defined as the sum of the individual waste load allocations (WLAs) from point sources, load allocations (LAs) from nonpoint sources and background loading, plus an appropriate margin of safety (MOS). Loading from all pollutant sources must not exceed a water body’s Loading Capacity (LC), the amount of pollutant loading that a water body can receive without exceeding water quality objectives. That is,

$$\text{TMDL} = \text{LC} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}.$$

Where Σ = the sum, LC = loading capacity, WLA = waste load allocations, LA = load allocations (including load allocations for natural and background sources) and MOS = a margin of safety.

Elements of a TMDL include:

- a problem statement that identifies the context, background and the nature of the impairment being addressed by the TMDL;
- a numerical water quality target or targets;
- an identification and quantification of sources and source loads;
- a maximum load of the contaminant that will not adversely impact beneficial uses;
- a mathematical linkage analysis between the water quality target and amount or load of contaminant;
- an allocation of portions of the necessary load reduction to the various sources; and
- a margin of safety that takes into account uncertainties and consideration of seasonal variations.

A.1.1.2 Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act, which is contained in Division 7 of the California Water Code (CWC), establishes the responsibilities and authorities of each Regional Water Quality Control Board, including authority and responsibility for regional water quality control and planning. The Regional Board establishes water quality objectives and programs to implement those objectives by amending the Central Valley Region's Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Basin Plan).

A.1.2 Scope of This Document

Diazinon is a broad spectrum, organophosphorus (OP) pesticide used for urban and agricultural pest control in the Sacramento and Feather River Watersheds. Both the lower Sacramento and lower Feather Rivers are currently listed on the 303(d) list as impaired by toxic diazinon concentrations. This appendix (the TMDL report) presents the elements of a TMDL listed in Section A1.1. The geographic scope of this document is the lower Sacramento River, from Shasta Dam to the confluence with the Sacramento-San Joaquin Delta at the I Street Bridge in Sacramento, and the 60 mile reach of the lower Feather River, from Oroville Dam to the confluence with the Sacramento River at Verona. This appendix also provides the technical basis for the loading capacity and allocations in the proposed Basin Plan Amendment (see also Section 2 and Section 5.5 of the Basin Plan Amendment Staff Report).

A.2 Problem Statement

A.2.1 Introduction

The purpose of the problem statement is to provide the context and background for the TMDL and describe the water quality impairments being addressed. This problem statement further defines the water body segments and pollutants being addressed by the TMDL, the relevant water quality standards, the basis for the 303(d) listings, and provides an overview of the environmental characteristics, hydrology and land uses of the affected watershed.

A.2.2 Environmental Characteristics of the Sacramento and Feather River Watersheds

The Sacramento River Basin, which includes both the Sacramento Valley (Figure A2.1) and the Lake Shasta watershed, covers approximately 27,000 square miles. It extends from just north of the Oregon border south to the River's confluence with the Sacramento/San Joaquin Delta (Delta). The Sacramento River is 320 miles long, with the upper Sacramento flowing from just south of the Oregon border into Lake Shasta, the middle Sacramento flowing from Lake Shasta to Red Bluff, and the lower Sacramento flowing 120 miles from Red Bluff to the Delta. The Sacramento River, in terms of both flow and drainage area, is the largest river in California. On average, over 22 million acre-feet of water flow from the Sacramento River watershed each year (Dileanis et al., 2002).

The Central Valley extends more than 400 miles from near the City of Redding in the north to the Tehachapi Mountains in the south. The Sacramento Valley comprises the northern third and the San Joaquin Valley the southern two-thirds of the Central Valley. The Sacramento Valley extends from near the City of Redding to the confluence with the Delta near downtown Sacramento, and from the Coast Ranges east to the Sierra Nevada. The upper Sacramento and Feather Rivers, as well as most of the other tributaries to the Sacramento River, are impounded by dams above the Sacramento Valley border. The lower Feather River is the largest natural tributary to the Sacramento River and flows approximately 60 miles through the Sacramento Valley from Oroville Dam to the confluence with the Sacramento River at Verona.

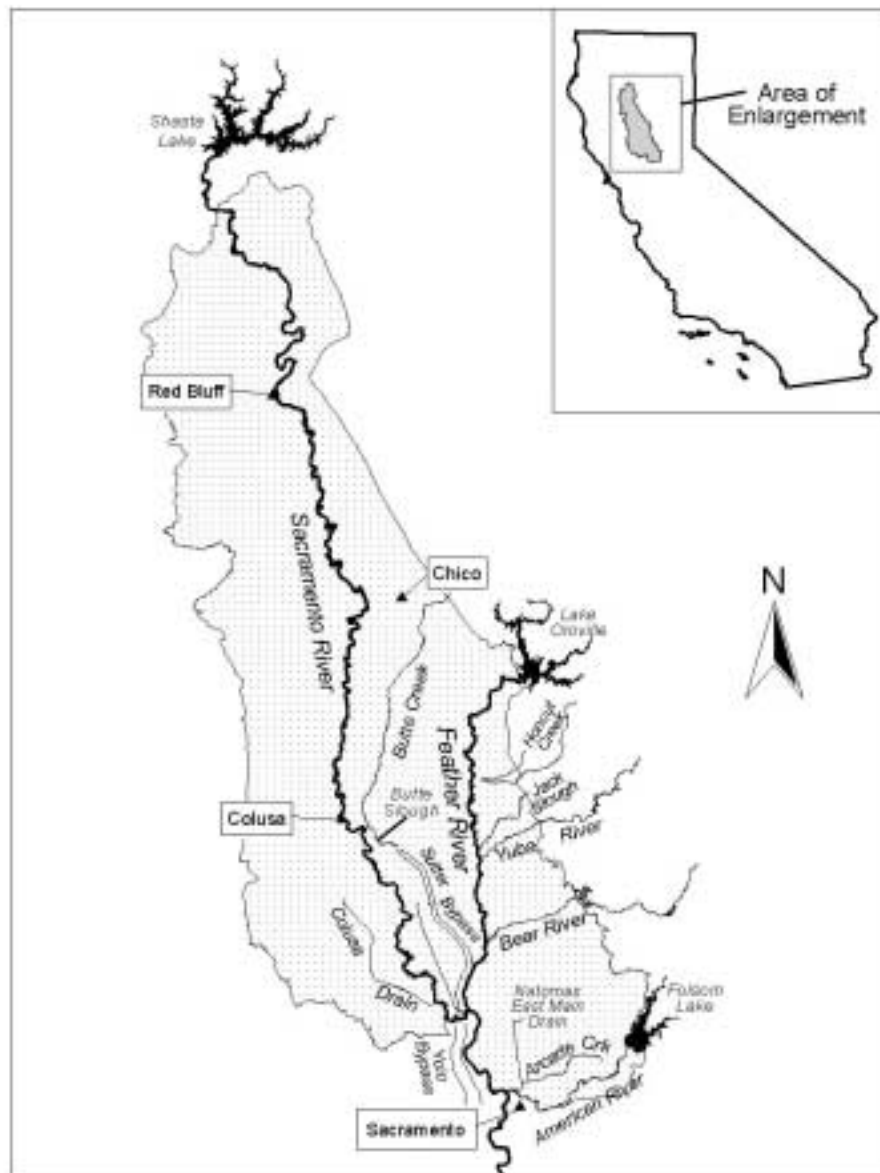


Figure A2.1. The Sacramento Valley

The climate in the Sacramento Valley is semi-arid. Rainfall in the Sacramento Valley occurs throughout the year but is more pronounced during the months of October through May, and is generally greatest during the months of January, February, and March. Little to no rainfall occurs from June through September.

A.2.3Land Uses

Agriculture is the dominant land use in the Sacramento Valley, followed by urban development. About 3,400 square miles of Sacramento Valley land are irrigated to sustain a variety of crops such as rice, fruits, nuts, tomatoes, sugar beets, alfalfa, corn and wheat. About 290 square miles in the Sacramento Valley are devoted to stone fruit and almond orchards, mostly in the northern and central parts of the valley (DWR, 2001a). More than 2 million people reside in the Sacramento Valley. The largest cities within the Sacramento Valley include Redding, Red Bluff, Chico, and Sacramento. Most of the urban area is concentrated in the southern part of the Sacramento Valley, near the city of Sacramento.

In the Sacramento Valley, total agricultural land use comprises 2,159,903 acres with the greatest percentage, 25.3 percent (547,301 acres), used for growing and cultivating rice. About 16 percent (336,366 acres) of the agricultural land in the Sacramento River Watershed is used to grow deciduous fruits and nuts, and grain and hay crops are grown on nearly 15 percent (322,569 acres). Table A2.1 lists land uses within the Sacramento Valley based upon California Department of Water Resources (DWR) land use data for Butte, Colusa, Glenn, Placer, Sacramento, Shasta, Sutter, Tehama, Yolo, and Yuba counties (DWR, 2001a).

Table A2.1. Agricultural and Urban Land Use in , Butte, Colusa, Glenn, Placer, Sacramento, Shasta, Sutter, Tehama, Yolo, and Yuba Counties, 1989-1998. (data from DWR, 2001a)

Land Use	Acres	Percent of Total Agricultural Land
Agricultural Land Use		
Rice	547,301	25.3
Deciduous Fruits & Nuts	336,366	15.6
Grain & Hay Crops	322,569	14.9
Pasture	282,428	13.1
Field Crops	264,550	12.2
Truck, Nursery & Berry Crops	167,625	7.8
Idle	160,850	7.4
Semi-Agricultural & Incidental to Agricultural	38,133	1.8
Citrus & Subtropical Fruit	31,268	1.4
Vineyards	8,813	0.4
Total Agricultural Land Use	2,159,903	
Total Urban Land Use	273,032	

A.2.4Hydrology

Hydrologically, the Sacramento Valley is a highly managed area, with reservoirs that are used for water supply and flood control on all the major tributaries of the lower Sacramento River, as well as diversions for municipal and agricultural uses and levies and bypasses for additional flood control. Areas reclaimed by these hydrologic manipulations are now highly productive agricultural lands and urban areas that are located in the historic flood plains of the Sacramento and Feather Rivers.

In addition to the natural hydrologic processes of rainfall runoff, snowmelt, and base flow from groundwater discharge, the flows in the lower Sacramento and Feather Rivers are greatly affected by reservoir releases, water diversions, irrigation return flows, and diversions through bypasses. Both the Sutter and Yolo bypasses have the capacity to carry larger volumes of water than the Sacramento River channel when they are utilized to prevent flooding during high flows.

A.2.5 Beneficial Uses and Water Quality Standards

A.2.5.1 Water Quality Control Plan

The Regional Board's Basin Plan was developed to protect surface water and groundwater quality throughout the Sacramento River and San Joaquin River basins. The Basin Plan designates beneficial uses for each water body within the Sacramento and San Joaquin River Basins, and water quality objectives to protect these uses. The Basin Plan also contains implementation programs to achieve and maintain compliance with water quality objectives. For surface waters, the beneficial use designations and water quality objectives contained in the Basin Plan (along with the State's Antidegradation Policy) constitute water quality standards under the federal Clean Water Act.

A.2.5.2 Beneficial Uses

Beneficial Uses designated by the Regional Board for the lower Sacramento and lower Feather Rivers are municipal and domestic supply (MUN); agriculture irrigation (AGR); contact recreation (REC-1); non-contact recreation (REC-2); warm and cold freshwater habitat (WARM and COLD); warm and cold migration and spawning (MIGR and SPWN) and wildlife habitat (WILD). Navigation (NAV) has also been designated as a beneficial use for the Sacramento River (CRWQCB-CVR, 1998).

A.2.5.3 Water Quality Objectives

The water quality objectives in the current Basin Plan that are relevant to diazinon in the Sacramento and Feather Rivers are summarized below.

A.2.5.3.1 Pesticides

The Water Quality Objectives for pesticides and potentially applicable to diazinon in inland surface waters listed in Chapter III of the Basin Plan include:

- "No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses."
- "Pesticide concentrations shall not exceed those allowable by applicable antidegradation policies."
- "Pesticide concentrations shall not exceed the lowest levels technically and economically achievable." (CRWQCB-CVR, 1998)

A.2.5.3.2 Toxicity

The narrative toxicity objective in the Basin Plan states, in part, "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life." The narrative toxicity objective further states that "The Regional Water Board will also consider ... numerical criteria and guidelines for toxic substances developed by the State Water Board, the California Office of Environmental Health Hazard Assessment, the California

Department of Health Services, the U.S. Food and Drug Administration, the National Academy of Sciences, the U.S. Environmental Protection Agency (USEPA) and other appropriate organizations to evaluate compliance with this objective” (CRWQCB-CVR, 1998).

If adopted, this Basin Plan Amendment would establish numerical water quality objectives for diazinon. The diazinon objectives were developed by the California Department of Fish and Game (CDFG) (Siepmann and Finlayson, 2000) and are shown in Table A2.2. The criteria were determined by using methods established by the USEPA for protection of aquatic life (USEPA, 1985).

Table A2.2. CDFG Freshwaters Aquatic Life Criteria for Diazinon (criteria from Siepmann and Finlayson, 2000)

Criterion Values	Criterion Type	Criterion Recurrence Period
80 ng/l (nanograms per liter) or 0.080 µg/L (micrograms per liter)	Acute, Criteria Maximum Concentration (CMC)	1-hour average; not to be exceeded more than once every 3 years
50 ng/l or 0.050 µg/L	Chronic, Criteria Continuous Concentration (CCC)	4-day average; not to be exceeded more than once every 3 years

A.2.6 Sources And Effects of Diazinon in Water

Diazinon is a man-made pesticide. The sources of diazinon in the lower Sacramento and Feather Rivers are urban and agricultural applications. In the Sacramento Valley, diazinon is used to exterminate destructive pests and insects such as aphids, spider mites, fleas, ants, roaches, and boring insects. A fraction of urban and agricultural diazinon applications can reach surface water during rainfall or irrigation events, when residual diazinon migrates with stormwater runoff, irrigation return water, or aerial drift, then enters tributaries that flow into the Sacramento and Feather Rivers. Diazinon use patterns and environmental fate are discussed in detail in the Source Analysis (Section A.4).

Diazinon can be acutely toxic to invertebrate and vertebrate aquatic life, wildlife, and humans. When ingested by an organism, diazinon can systemically circulate in the affected organism’s body, travel to nerve cells and react with the enzyme acetylcholinesterase (AChE) that is involved in nerve impulse transmission, causing the nerve impulses to fire to exhaustion. Acute toxicity due to diazinon exposure causes neurobehavioral, cognitive and neuromuscular function, and respiratory failure causing death of the affected organism. Chronic toxicity due to diazinon exposure involves less

severe neurobehavioral, cognitive, and neuromuscular symptoms and reproductive problems such as reduced rate of egg production and increased rate of egg failure.

Diazinon has a relatively short half-life when compared to other pesticides, and therefore is only moderately persistent in the environment, as discussed below in the source analysis. Diazinon has only a moderate potential to bioconcentrate in aquatic organisms (Giddings et al., 2000).

A.2.7 Monitoring Data

Several studies, summarized in Tables A2.3 and A2.4 and in Appendix D (conducted by the United States Geological Survey, California Regional Water Quality Control Board-Central Valley Region, and the California Department of Pesticide Regulations, and others) have detected diazinon concentrations at levels of concern in the lower Sacramento and lower Feather Rivers. Water samples collected from the lower Sacramento River in 1993 and 1994 and the Feather River in 1994 and 1998 indicated that diazinon was present in concentrations toxic to *Ceriodaphnia dubia*, an invertebrate organism (zooplankton) used in USEPA toxicity tests of water samples (MacCoy et al., 1995; Domagalski, 1996; Kuivila and Foe, 1995; Holmes et al., 2000; Larsen et al., 1998).

Samples collected from the Sacramento River at Rio Vista in February 1993 were found to be toxic to *Ceriodaphnia dubia*, and diazinon concentrations detected in these samples appear high enough to account for most of the toxicity (Kuivila and Foe, 1995). While Rio Vista is located in the Delta, samples collected upstream in the Sacramento River at the city of Sacramento during the same period in 1993 were found to have higher diazinon concentrations than those found in the samples from the Sacramento River at Rio Vista (Kuivila and Foe, 1995). Toxicity testing of samples collected in January 1997 from Sacramento Slough, a tributary of the Sacramento River influenced by upstream orchard runoff, showed significant *Ceriodaphnia* toxicity. Subsequent Toxicity Identification Evaluation (TIE) analysis identified diazinon as the cause of the observed toxicity (Foe et al., 1998). Toxicity testing using Feather River water in February 1998 showed significant *Ceriodaphnia* toxicity and subsequent Toxicity Identification Evaluation (TIE) analysis identified diazinon as the primary contaminant responsible for the observed toxicity (Larsen et al., 1998).

Diazinon concentrations found in samples collected from the lower Sacramento River in 1992, 1993, 1994, 1997, 1998 and 2001 and from the lower Feather River in 1994, 1997, 1998, and 2000 exceed the CDFG recommended acute and/or chronic criteria for diazinon (MacCoy et al., 1995; Domagalski, 1996; Kuivila and Foe, 1995; Holmes et al., 2000; Dileanis et al., 2002; Dileanis, 2002; Nordmark, 1998; LWA, 2002). Tables A2.3 and A2.4 summarize diazinon detections and exceedances of the CDFG recommended criteria for the lower Sacramento and Feather Rivers from 1991 through 2001. The locations of the sampling sites are shown in Figure A4.2.

** Not all of the 2003 data for this site is currently available.

Table A2.3 (Continued) Sacramento River Diazinon Concentrations in Exceedance of CDFG Aquatic Life Criteria

Monitoring Site: Sacramento River at -	Dormant Season*	Max. Concentration (ng/L)	Number of Samples Collected	Number of Samples Exceeding CDFG CMC (80 ng/L)	Number of Samples Collected in Jan and Feb	Number of Samples Exceeding CDFG CMC in Jan and Feb	Number of 4-day Averages Calculated	Number of 4-day Averages Exceeding CDFG CCC (50 ng/L)	Number of 4-day Averages Calculated for Jan and Feb	Number of 4-day Averages Exceeding CDFG CCC in Jan and Feb
Alamar Marina/ Veterans Bridge	1995	70	3	0	3	0	0	0	0	0
	1997	21	11	0	2	0	0	0	0	0
	1998	171	40	7	27	7	20	9	16	9
	1999	21	38	0	26	0	18	0	16	0
	2000	65	56	0	39	0	35	0	31	0
	2001	76.5	30	0	15	0	7	0	7	0
	2002	28	24	0	10	0	2	0	2	0
	2003	51	23	0	19	0	11	0	11	0
2.5 mi. South of Confluence with Feather R.	1993	no detect	3	0	0	0	0	0	0	0
	1994	110	49	1	9	1	0	0	0	0
Bryte	1997	65	24	0	18	0	16	2	12	2
* Dormant seasons start in December of the previous calendar year. For example, the 1994 dormant season refers to December 1993 through November 1994.										

Table A2.4 Feather River Diazinon Concentrations in Exceedance of CDFG Aquatic Life Criteria

Monitoring Site	Dormant Season*	Max. Concentration (ng/L)	Number of Samples Collected	Number of Samples Exceeding CDFG CMC (80 ng/L)	Number of Samples Collected in Jan and Feb	Number of Samples Exceeding CDFG CMC in Jan and Feb	Number of 4-day Averages Calculated	Number of 4-day Averages Exceeding CDFG CCC (50 ng/L)	Number of 4-day Averages Calculated in Jan and Feb	Number of 4-day Averages Exceeding CDFG CCC in Jan and Feb
Feather River near Outlet	1994	834	30	7	29	7	14	8	14	8
	1996	no detect	10	0	1	0	0	0	0	0
	1997	97.7	13	1	2	1	0	0	0	0
	1998	515	6	1	3	1	0	0	0	0
	2000	129.5	20	1	16	1	6	2	6	2
	2001	27.5	17	0	12	0	6	0	6	0
	2002	47	13	0	9	0	2	0	2	0
	2003	22	16	0	16	0	11	0	11	0
Feather River at Yuba City	1994	165.5	28	6	27	6	11	4	11	4
	2000	97	9	2	9	2	0	0	0	0
	2001	20	10	0	10	0	4	0	4	0

* Dormant Seasons start in December of the previous calendar year. For example, the 1994 dormant season refers to December 1993 through November 1994.

Chlorpyrifos, another organophosphorus pesticide, has been found to be present at levels of concern in several Central Valley waterways (CVRWQCB-CVR, 2001). When diazinon and chlorpyrifos are present in a mixture, these two compounds display additive toxicity (Bailey *et al.*, 1997). In the Sacramento and Feather Rivers, chlorpyrifos is not detected frequently, and the levels detected are well below the CDFG criteria for chlorpyrifos. Table A2.5 summarizes the available monitoring data for chlorpyrifos from 1991-2002. The CDFG recommended criteria concentrations for chlorpyrifos are a 20 ng/L 1-hour average concentration not to be exceeded more than once every three years, and a 14 ng/L 4-day average concentration not to be exceeded more than once every three years (Siepmann and Finlayson, 2000).

Table A2.5. Summary of Chlorpyrifos Data for the Sacramento and Feather Rivers (1991-2001)

Location	Years	Sample Frequency and Timing	number of samples collected	number of detections	maximum chlorpyrifos concentration (ng/L)	quantification limit (ng/L)
Sacramento River at Hamilton city	99-02	Single samples collected during storm and non-storm events	24	0	NA	50
Sacramento River at Colusa	1994	dormant season storm event samples collected daily	17	0	NA	5
	1999-2002	Single samples collected during storm and non-storm events	26	0	NA	50
	2001	dormant season storm event samples collected daily	10	0	NA	5
Sacramento River at Alamar (Veteran's Bridge)	99-02	Combination of single samples collected during storm and non-storm events, and monthly, year round sampling	48	0	NA	50
	2001	dormant season storm event samples collected daily	11	2	2 (estimated)	5
Sacramento River at Sacramento	1991-1994	samples collected 3 times per week, year round	463	0	na	28 or 44
	2000	dormant season storm event samples collected daily	16	6	5	4
	2001	dormant season storm event samples collected daily	12	0	NA	5
Sacramento River at Freeport*	1996-2001	samples collected monthly, year-round	62	3	6	4 or 5
Sacramento River at River Mile 44*	2000-2002	Combination of single samples collected during storm and non-storm events, and monthly, year round sampling	21	0	NA	50
Feather River Near its Outlet	1994	dormant season storm event samples collected daily	13	0	NA	5(MDL)
	2000	dormant season storm event samples collected daily	11	3	6	4
	2000-2002	Combination of single samples collected during storm and non-storm events, and monthly, year round sampling	14	0	NA	50
	2001	dormant season storm event samples collected daily	10	2	2 (estimated)	5

*The Sacramento at River Mile 44 and at Freeport are located within the Delta

Sources: Dileanis et al. 2002, Dileanis 2002, Domogalski, 2000, Holmes et al. 2000, Larry Walker Associates, 2003, McCoy et al. 1995, USGS National Water Information System

A.2.8 Extent of Impairment

Beneficial uses affected by diazinon contamination in the lower Sacramento and Feather Rivers are Warm (WARM) and Cold (COLD) Freshwater Habitat (CVRWQCB, 1998). Based on the available data, the lower Sacramento and Feather Rivers have been placed the 303(d) list as impaired due to toxic diazinon concentrations (SWRCB, 1999). The Sacramento River is listed as impaired for 30 miles from Knights Landing downstream to the Delta, which begins at the I Street Bridge in Sacramento. The available data suggests, however, that the lower Sacramento River is impaired by diazinon for 120 miles, from Red Bluff to the Delta. The lower Feather River is listed as impaired for 60 miles, from Oroville Dam to the confluence of the Feather and Sacramento rivers at Verona. The available monitoring data indicate that the impairment for both of these rivers is seasonal in nature. Nearly all samples exceeding the CDFG criteria were collected in January and February, as shown in Figure A2.2 and Figure A2.3.

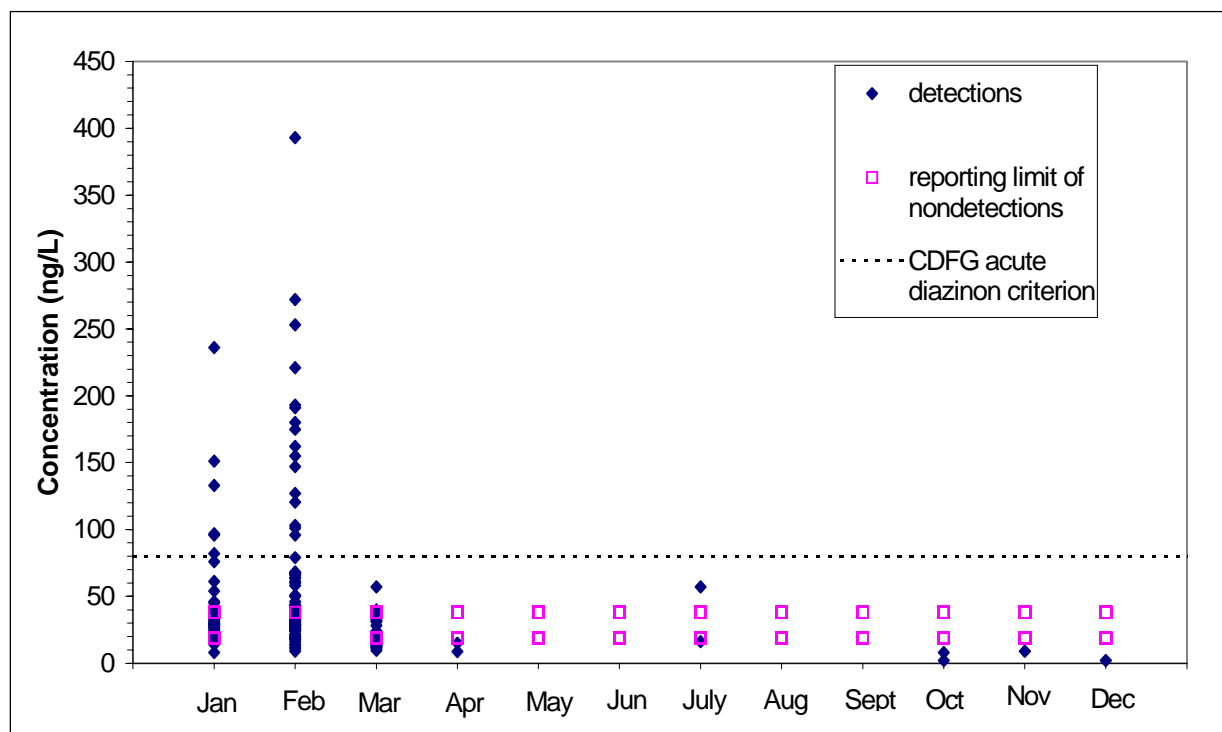


Figure A2.2. Diazinon Concentrations in the lower Sacramento River at Sacramento (1991 to 2001) Grouped by Month.

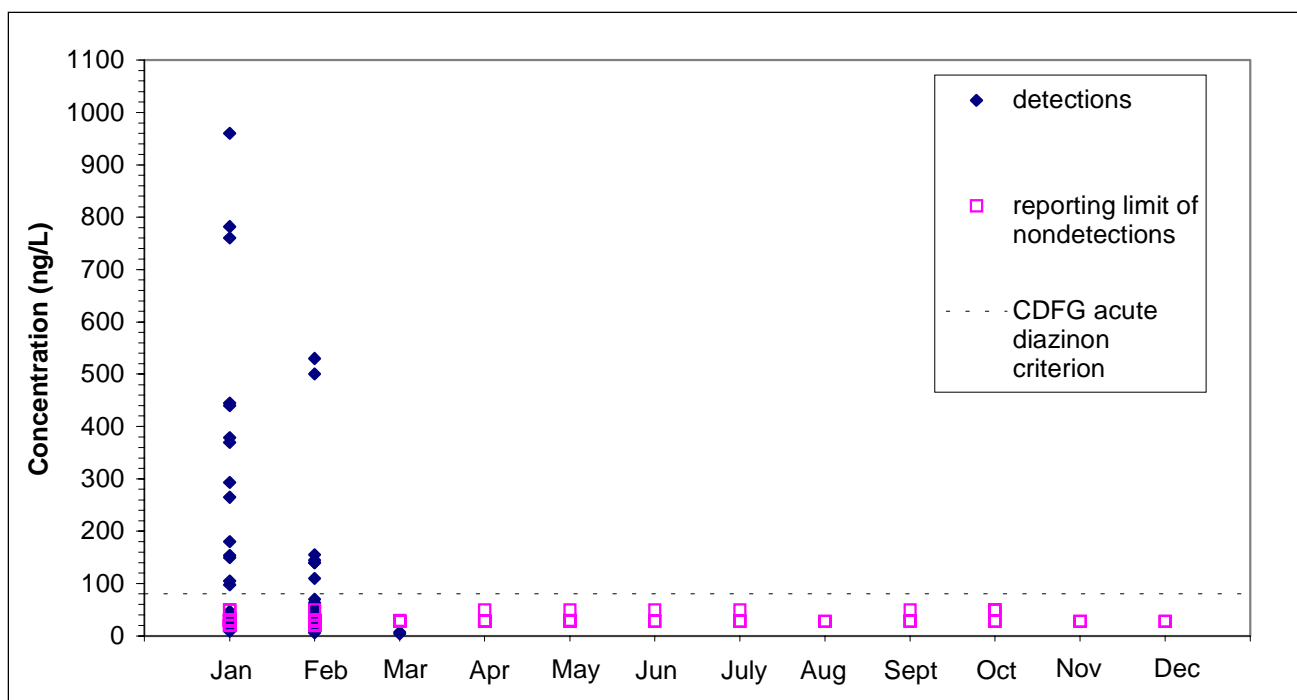


Figure A2.3. Diazinon Concentrations in the lower Feather River Near its Outlet (1994-2002) Grouped by Month

A.3 Numeric Targets

Section 303(d)(1)(C) of the Clean Water Act states that TMDLs “shall be established at a level necessary to implement the applicable water quality control standards....” Once established, the numeric targets identify the specific instream goals or endpoints for the TMDL, which are expected to lead to the attainment of the water quality standards established in the Basin Plan. The numeric targets for the lower Sacramento and Feather River Diazinon TMDL must be consistent with existing water quality objectives for the Sacramento and Feather Rivers and be protective of their designated beneficial uses. The final numeric targets for this TMDL will be determined based on water quality objectives adopted for the lower Sacramento and Feather Rivers via a Basin Plan Amendment.

Based on the evaluation of alternatives contained in the Water Quality Objectives section of the Basin Plan Amendment Staff Report, Regional Board staff are recommending that the most appropriate water quality objectives would be the diazinon criteria derived by CDFG: 50 ng/L (nanograms per liter) 4-day average and 80 ng/L 1-hour average. For the purpose of describing the TMDL, it is assumed that the numeric targets will be the proposed Water Quality Objectives. The TMDL can be modified based on the water quality objectives adopted by the Regional Board.

A comparison of the proposed Water Quality Objectives to the existing conditions (summarized in Tables A2.3 and A2.4, above) indicates these criteria are frequently exceeded, although the frequency and magnitude of exceedances appears to be declining with time. These apparent declines are due to a number of factors including the decreased use of diazinon discussed in the Basin Plan Amendment Staff Report.

A.4 Source Analysis

A.4.1 Introduction

This Source Analysis describes the sources of diazinon to the lower Sacramento and Feather Rivers, and the magnitude, timing and seasonality of diazinon concentrations and loads. The environmental properties and fate of diazinon are described, and data on the volume, location and timing of diazinon applications are compiled and examined.

A.4.2 Information Used for the Source Analysis

The sources of the diazinon concentration, diazinon use and stream flow data used in this source analysis are summarized below. When appropriate, additional information, results and observations from previous studies are also included.

A.4.2.1 Sources of Diazinon Concentration Data

From 1992 through 2001, numerous studies funded and conducted by several agencies and institutions have examined concentrations of diazinon in surface water in the lower Sacramento River watershed. The titles of these studies, as well as the sites and periods of sampling are summarized in Appendix D. For data on diazinon concentration in surface water in the Sacramento Valley, the time period examined is from January 1992 through March 2002. The diazinon concentration data from the studies listed in Appendix D was acquired from various sources, including the California Department of Pesticide Regulation (CDPR) Surface Water Database (SWDB) (CDPR, 2001) and the US Geological Survey (USGS) National Water Information System (NWIS) database (USGS, 2002).

A.4.2.2 Sources of Diazinon Use Data

Pesticide use reports track the amount of a pesticide active ingredient that is used in agricultural settings and by professional applicators in urban settings. Pesticide use reports contain the area treated, the amount of pesticide product and active ingredient applied, and the location of the application. Application locations for agricultural uses are reported by the section(s) (an area that is one square mile in size) containing the application. Application locations for urban uses are reported by county. Pesticide use data was obtained from the CDPR Pesticide Use Report (PUR) database (CDPR, 2001) for diazinon use in counties within the Sacramento Valley for March 1991 through March 2001.

A.4.2.3 Sources of River Flow Data

Flow data from the USGS (USGS, 2002) and DWR (DWR, 2001c) gaging stations in the lower Sacramento and Feather rivers were obtained to calculate diazinon loads to these water bodies.

A.4.3Diazinon Transport and Environmental Fate

The chemical and physical properties of diazinon largely determine its fate and transport in the environment. Diazinon is moderately mobile and persistent in the environment. Due to its mobility and widespread use, diazinon has been detected in air, rain, fog, soil, surface water, and groundwater (USEPA 2000b).

Diazinon is released into the atmosphere during and following agricultural and urban applications. Diazinon has a low vapor pressure (ranging from 6.4 to 18.7 milliPascals (mPa) at 20 degrees C (USDA, 1995)) and Henry's law constant (estimated at 0.072 Pa-m³/mol (USDA, 1995)), indicating that a small to negligible fraction of applied diazinon is expected to volatilize from soil, crops, surface water or other surfaces into the atmosphere. Atmospheric diazinon can exist in particulate and vapor forms, as well as a solute dissolved in fog (Seiber et al. 1993). Atmospheric vapor-phase diazinon is degraded by reacting with photochemically-produced hydroxyl radicals, and the estimated half life for this reaction is 4 hours (NLM, 2002). Particulate-phase diazinon may be removed from the air by wet and dry deposition (NLM, 2002). Diazinon also absorbs light in the environmental spectrum and has the potential for direct photolysis in the atmosphere (NLM, 2002). Once in the atmosphere, diazinon can be transported by bulk movement of air and is subject to deposition processes (Larkin and Tjeerdeema, 2000). Atmospheric transport of diazinon from the Central Valley to the Sierra Nevada Mountains has been found to occur, although diazinon levels decreased significantly with distance and elevation (Zabik and Seiber, 1993). Both dry and wet deposition processes can deposit atmospheric diazinon onto the ground surface, onto vegetation, or directly into surface waters.

Diazinon has a low to moderate tendency to adsorb to soil, with reported organic carbon adsorption coefficient (K_{oc}) values of 1,007 to 1,842 (USDA, 1995). In soils, diazinon can be degraded by hydrolysis, microbial degradation and photolysis, lost to surface and/or groundwater via runoff and/or leaching, and lost to the atmosphere via volatilization. Diazinon degrades more rapidly in acidic soils than neutral or alkaline soils, and degrades more rapidly in nonsterilized soils than sterilized soils (Larkin and Tjeerdeema, 2000). Field dissipation half-life is a measure of the overall rate of disappearance of a pesticide from soil by leaching, runoff, hydrolysis, photolysis and microbial degradation. Reported diazinon field dissipation half-life values range from 3 to 54 days, with the range of 3 to 13 days considered to be the most representative of actual field conditions (USDA, 1995). As a rule of thumb, the time needed for about 90 percent of the pesticide residue to dissipate is 4 times the field dissipation half-life (USDA, 1995). Reported values for diazinon's half-life on vegetation range between 2 and 14 days (Sheipline, 1993).

Diazinon is moderately soluble in water with reported solubility values ranging from 40 to 60 parts per million (ppm) at 20 to 30 degrees C (USDA, 1995). The solubility of diazinon is

relatively high for a pesticide (Larkin and Tjeerdema, 2000), and diazinon's solubility values indicate that solubility is probably not limiting the movement of diazinon into solution for transport in moving water. Due to diazinon's moderate solubility and low to moderate tendency to adsorb to soil, it can move off of crops, soil and other surfaces and into surface water in runoff from rainfall and irrigation runoff. Atmospheric deposition has the potential to directly contribute to surface water diazinon concentrations. Sediment associated diazinon can also be mobilized by sediment runoff and transport of sediments in surface waters, but this may not be as important a mechanism of transport for diazinon, as approximately 98% of the diazinon in San Francisco Bay is reported to occur in the dissolved phase (Domagalski and Kuivila, 1993). In water, diazinon can be degraded by hydrolysis, photolysis, and microbial degradation, and lost via volatilization. All of these processes are strongly influenced by the pH, temperature, salinity and purity of water. The rate of hydrolysis of aqueous diazinon increases with high or low pH. Reported values for diazinon's hydrolysis half-life in water have been reported at 12 days (pH 5), 138 days (pH 7), and 77 days (pH 9) (Giddings et al., 2000). Reported values for diazinon's photolysis half-life in water range from and 15 to 25 days (Giddings et al. 2000). Estimates of diazinon's half-life in water in incubated bottles range from 14 to 99 days, and from 5 to 25 days in larger, open, outdoor experimental systems (Giddings et al., 2000).

Diazinon has a low to moderate potential to bioconcentrate in aquatic organisms, with reported bioconcentration factors ranging from 4.9 to 152 (NLM, 2002). Depuration of accumulated diazinon is rapid, with experimental results showing 96 to 97 percent of accumulated diazinon residues eliminated from fish tissues within seven days (USEPA, 2000b).

A.4.4 Methodology for Analyzing Sources

The sources of diazinon in the lower Sacramento and Feather Rivers were analyzed by examining the locations and amount of diazinon use, the available water concentration data, and the loads of diazinon being transported in Sacramento Valley waterbodies. Diazinon use, concentrations and loads were examined for six sub-watersheds (defined below) within the Sacramento Valley, and also for the land uses on which there is significant diazinon use. Because the significant diazinon concentrations are seen during the months of January and February, diazinon use during the orchard dormant spray season and diazinon concentrations and loads during January and February are the main focus of the analysis below.

The six sub-watersheds of the Sacramento Valley used to analyze the sources of diazinon (Figure A4.1) are: the Sacramento River Above Colusa; the Colusa Drain; the Sutter/Butte Basin; the Lower Feather River Basin; the Natomas Cross Canal Area; and the American River. These sub-watersheds were defined in order to group areas of diazinon use that drain to a specific point or reach of the river, such that diazinon loading from each sub-watershed can be estimated. The geography of each sub-watershed is described in Section A4.6.

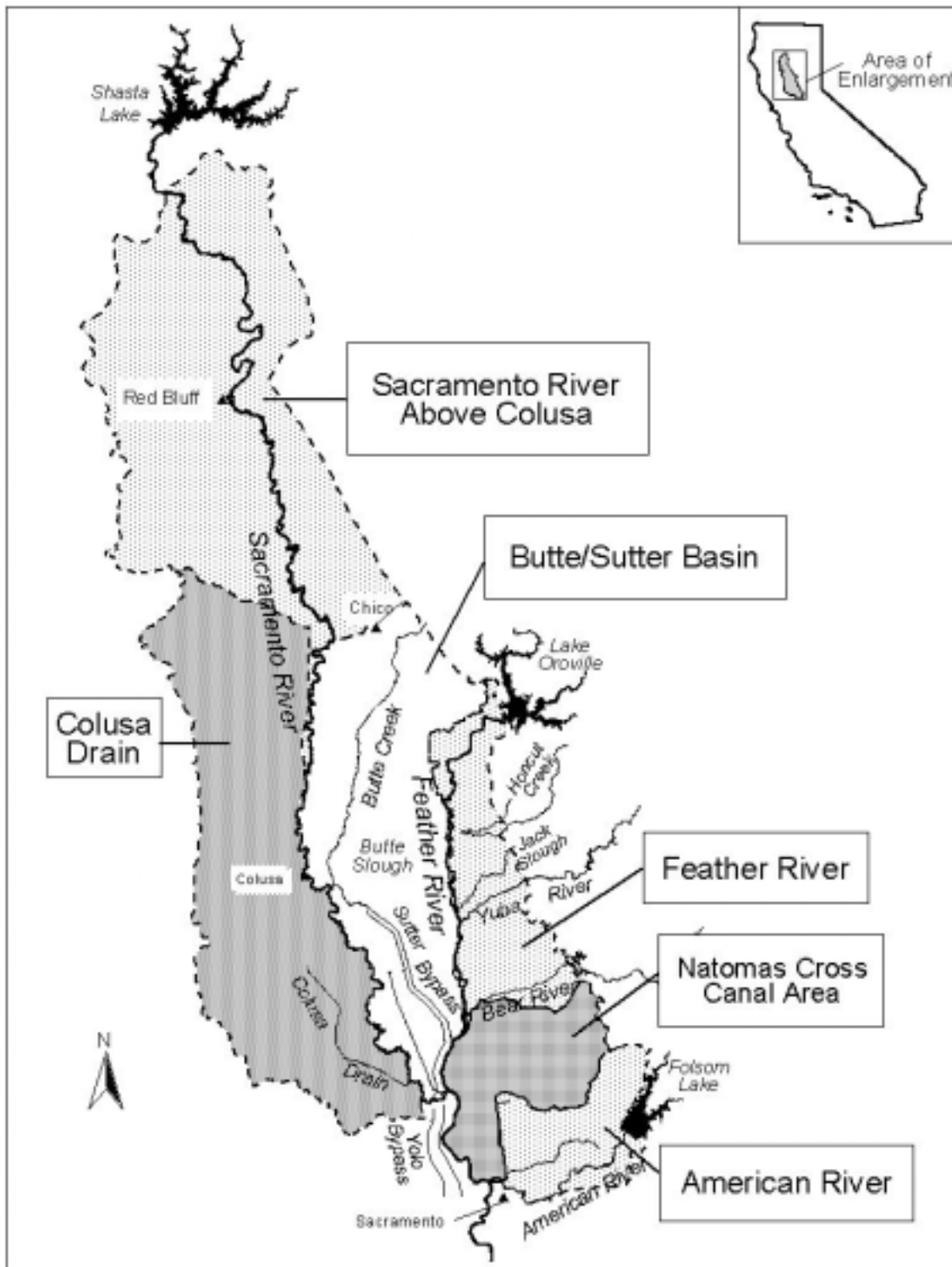


Figure A4.1. Sacramento Valley Sub-watersheds

Diazinon use was summed from pesticide use report data for each cartographic section during the dormant spray season for each year examined. Geographic Information Systems (GIS) software was then used to prepare maps showing the locations of the

applications, and to determine the total applications within each sub-watershed. Diazinon concentrations in water samples collected at locations within each sub-watershed were summarized, and compared to upstream land uses.

When flow information was available for the same time period and location that diazinon concentrations were, loads were calculated. A load is the quantity of a pesticide in the water passing a sampling site over a given period (e.g. a single day). Daily diazinon loading rates at sampling sites were calculated by:

$$\text{Load}_t = C_t \times Q_t \times 0.002446 \quad \text{Equation A1}$$

where:

Load_t = amount of pesticide passing the sampling site in the water during a given time period, t, g/day (grams per day)

C_t = pesticide concentration at time t, ng/L

Q_t = flow rate at time t, cfs (cubic feet per second)

0.002446 = multiplier to convert load to units of g/day

If the concentrations and flow rates were collected only once per day at a particular sampling site, then these data were assumed to be daily average values. If multiple concentrations and/or flow measurements were made at a site during a single day, the average concentration and/or flow for that day was used in Equation A1.

A.4.5Diazinon Sources in the Sacramento Valley

A.4.5.1 Diazinon Use in the Sacramento Valley

Diazinon is used in urban and agricultural settings to exterminate destructive insects such as aphids, spider mites, fleas, ants, roaches, San Jose scale and boring insects, such as the peach twig borer that damages fruit and nut trees. Diazinon was registered for use as a pesticide in the United States in 1956 and has been used in California for home, business, and agricultural pest control (USEPA, 2002). Diazinon formulation types include dusts, emulsifiable concentrates, granules, impregnated materials, liquids, microencapsulated, pressurized sprays, soluble concentrates, and wettable powders (USEPA, 2002).

In agricultural settings, diazinon is applied to orchards during the winter orchard dormant season, generally between mid-December and early March of each year. Diazinon is also applied during the fruit and vegetable growing season, between April and September. In urban settings, diazinon is applied throughout the year around structural foundations, on landscape vegetation, and also via commercial and residential pest control products such as pet collars, ear tags, and animal dips (Shepline, 1993).

Table A4.1 shows median (using data from March 1991 through March 2001) diazinon application amounts during each month for the most significant agricultural land uses within the

10 counties of the Sacramento Valley. These crops and other sites of use account for the over 99 % of the total reported diazinon use.

Table A4.1. Sacramento Valley Median (1991-2001) Diazinon Use (Pounds) by Month and Land Use (data from CDPR, 2001)

Use Category	January	February	March	April	May	June	July	August	September	October	November	December
Alfalfa ^a	0	0	73	25	0	0	0	0	0	0	0	0
Almond	19,332	987	117	70	803	302	838	778	124	0	0	921
Apple	154	209	96	502	73	19	16	18	0	0	0	1
Beans	0	0	0	0	80	2	7	0	0	0	0	0
Cucumber	0	0	0	0	15	131	34	38	4	0	0	0
Landscape Maintenance	63	70	178	170	154	217	348	237	134	103	54	57
Melon	0	0	0	0	88	134	89	172	19	0	0	0
Nursery	53	1	6	25	32	3	16	42	6	26	5	3
Peach	7,675	1,855	32	25	73	91	88	0	0	0	0	1,023
Pear	13	27	13	1,476	4	102	10	38	8	2,227	670	0
Plum	1	71	7	7	52	3	9	0	0	0	0	0
Prune	17,819	13,120	2,767	1,177	3,794	2,836	1,034	21	0	0	0	1,210
Rights of Way	0	0	0	0	3	0	4	0	0	0	0	0
Structural Pest Control	1,386	1,253	1,275	1,234	1,289	1,803	1,578	1,434	1,755	1,875	1,476	1,506
Sugarbeet	0	0	0	13	37	26	0	3	0	0	0	0
Tomato	83	101	1,848	7,432	2,700	150	108	84	1	0	0	0
Walnut	3	3	0	451	2,286	3,095	3,408	7,848	454	0	0	0
Total of Median Diazinon Use	46,582	17,697	6,412	12,607	11,483	8,914	7,587	10,713	2,505	4,231	2,205	4,721

^aMedian values for alfalfa were calculated using data only from 1991 through 1996. Diazinon was not registered for use on alfalfa past 1996.

In urban settings within the Sacramento Valley, use of diazinon for structural pest control is relatively constant throughout the year, while use of diazinon for landscape maintenance purposes is highest in the summer, lower in spring and fall, and lowest in the winter (CDPR, 1999). Residential use of diazinon by non-professionals is not reported and the amounts used each month are therefore unknown.

In agricultural settings, diazinon use is seasonal with different commodities having different use patterns. In summer, agricultural use of diazinon is primarily on almonds, prunes and walnuts. In fall, agricultural diazinon use decreases, and most of the diazinon is applied on almonds, peaches, pears and walnuts. In winter, agricultural use of diazinon increases dramatically, making winter the season when the most diazinon is used. In winter, most of the diazinon is applied on almonds, peaches and prunes. In spring, agricultural use of diazinon decreases and most of the diazinon is applied to almonds, prunes, pears and tomatoes.

During winter, diazinon sprays are applied to stonefruit and nut trees while they are dormant. These spray applications typically occur from December through February, with occasional late applications in March. For the purposes of this report, the dormant spray season refers to the months of December through March, in order to cover the entire period of potential dormant sprays. In December, diazinon use on the stonefruit and nut trees typically begins in latter part of the month. Diazinon applications on stonefruit and nut trees increase significantly in January such that January is historically the highest reported diazinon use month during a given year. Diazinon applications on stonefruit and nut trees in February decrease significantly to amounts comparable to reported agricultural applications in December. Relatively small amounts of diazinon are applied to stonefruit and nut trees in March.

A.4.5.1.1 Diazinon Use Trends

Tables A4.2, A4.3 and A4.4 summarize dormant season diazinon applications for almonds, peaches, and prunes and plums (respectively) for Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Yuba, Yolo, Placer and Sacramento Counties for each year from December 1993-March 2001. Dried and fresh plums are combined for the purpose of this discussion. Average dormant season application rates for these crops vary between about 2 and 3 pounds per acre over this period, with a slight overall decline in mean and median application rates. The total area treated with diazinon has declined somewhat for all three crops, resulting in a general decrease in total use over this time period.

Table A4.2. Dormant Season Diazinon Applications on Almonds in the Sacramento Valley (Dec 1993 – March 2001)

Dormant Season ¹	Application Rate (Lbs/Acre)		Total Acres Treated	Total Acres Harvested	% (Total Acres Treated/ Total Acres Harvested)	Number of Applications	Total (Lbs) of Diazinon Applied
	Mean	Median					
1994	2.11	2.00	12,796	88,878	14.4	306	26,529
1995	2.05	1.99	5,495	85,012	6.5	118	12,023
1996	1.97	1.96	9,622	82,602	11.6	212	21,910
1997	2.33	1.98	6,554	84,679	7.7	142	13,668
1998	2.99	2.00	9,190	89,500	10.3	176	26,498
1999	1.99	1.98	13,959	97,763	14.3	254	29,614
2000	1.89	1.98	2,794	102,165	2.7	63	5,941
2001	1.86	2.00	5,146	NA ²	NA ²	157	9,154

Table A4.3. Dormant Season Diazinon Applications on Peaches in the Sacramento Valley (Dec 1993 – March 2001)

Dormant Season ¹	Application Rate (Lbs/Acre)		Total Acres Treated	Total Acres Harvested	% (Total Acres Treated/ Total Acres Harvested)	Number of Applications	Total (Lbs) of Diazinon Applied
	Mean	Median					
1994	2.19	2.47	5,527	15,219	36.3	227	13,992
1995	2.17	2.47	6,915	15,820	43.7	259	15,936
1996	2.17	2.00	6,161	16,497	37.3	230	14,415
1997	1.94	1.98	5,343	16,270	32.8	201	12,026
1998	1.85	1.97	4,342	17,556	24.7	151	8,998
1999	1.81	1.90	3,988	17,747	22.5	156	7,174
2000	1.85	1.97	4,295	18,298	23.5	155	8,538
2001	2.36	2.00	4,081	NA ²	NA ²	192	7,999

¹ Dormant spray seasons start in December of the previous calendar year. For example, the 1994 dormant spray season refers to December 1993 through March 1994.

² Data is not currently available.

Table A4.4. Dormant Season Diazinon Applications on Plums (dried and fresh) in the Sacramento Valley (Dec 1993 – March 2001)

Dormant Season ¹	Application Rate (Lbs/Acre)		Total Acres Treated	Total Acres Harvested	% (Total Acres Treated/ Total Acres Harvested)	Number of Applications	Total (Lbs) of Diazinon Applied
	Mean	Median					
1994	2.24	2.37	18,196	72,418	25.1	491	44,827
1995	2.11	2.00	24,867	72,662	34.2	598	53,328
1996	2.03	2.00	21,620	73,352	29.5	514	44,402
1997	1.87	1.96	18,624	69,413	26.8	480	35,194
1998	2.15	1.97	15,130	68,857	22.0	347	31,807
1999	1.78	1.95	14,786	76,777	19.3	300	28,886
2000	1.69	1.95	13,936	78,367	17.8	276	24,580
2001	1.68	1.99	12,411	NA ²	NA ²	288	21,195

Figures 1.5 and 1.6 in the Basin Plan Amendment Staff Report show the locations and relative amounts of agricultural diazinon applications during each dormant spray season from 1993/94 through 2000/2001. Table A4.5 summarizes total agricultural diazinon use for all crops during the dormant seasons from 1993 to 2001 for the entire Sacramento Valley and for each sub-watershed. Total dormant season agricultural use has declined significantly from the 1993/1994 dormant spray season to the 2000/2001 dormant spray season, and this decline appears to be occurring in each of the sub-watersheds. The total usages listed in Table A4.5 do not include applications from landscape maintenance, structural pest control and other reported non-agricultural uses or unreported uses. The urban use of diazinon is expected to significantly decrease in the near future due to USEPA's announcement to implement the phase out of diazinon use in urban environments due to human health concerns (USEPA, 2000a).

¹ Dormant spray seasons start in December of the previous calendar year. For example, the 1994 dormant spray season refers to December 1993 through March 1994.

² Data is not currently available.

**Table A4.5. Sacramento Valley Dormant Season Total
Agricultural Diazinon Applications Grouped by Year and Sub-
watershed**

	Dormant Season*							
	1994		1995		1996		1997	
Sub- watershed	Pounds Applied	Number of Applications	Pounds Applied	Number of Applications	Pounds Applied	Number of Applications	Pounds Applied	Number of Applications
Sacramento River above Colusa	16,352	182	19,719	251	16,791	271	14,622	208
Colusa Drain	8,928	130	10,027	122	13,095	184	6,718	132
Butte/Sutter Basin	50,623	644	33,576	501	41,350	539	30,349	450
Feather River	12,364	132	19,668	180	14,511	126	10,353	110
Natomas Cross Canal	477	26	960	28	674	18	763	28
American River	107	36	55	19	53	17	28	12
Total	88,851	1,150	84,005	1,101	86,474	1,155	62,833	940
	Dormant Season*							
	1998		1999		2000		2001	
Sub- watershed	Pounds Applied	Number of Applications	Pounds Applied	Number of Applications	Pounds Applied	Number of Applications	Pounds Applied	Number of Applications
Sacramento River above Colusa	21,870	201	14,516	149	7,930	106	6,944	100
Colusa Drain	12,142	131	19,312	162	5,940	78	8,182	96
Butte/Sutter Basin	27,146	319	26,085	382	18,311	279	20,251	292
Feather River	10,622	81	8,312	92	9,995	91	3,820	37
Natomas Cross Canal	372	12	97	1	164	9	516	5
American River	28	14	35	14	25	24	17	14
Total	72,180	758	68,357	800	42,365	587	39,730	544
*Dormant seasons start in December of the previous calendar year. For example, the 1994 dormant spray season refers to December 1993 through March 1994								

A.4.5.2 Diazinon Loads and Concentrations in the Sacramento Valley

Figure A4.2 shows the locations of the major diazinon monitoring sites on the lower Sacramento and Feather Rivers in relation to their major tributaries. The Sacramento River at Sacramento is the furthest downstream sampling point in the Sacramento River before the Delta, and receives flows from the entire Sacramento Valley, (excluding the southern areas draining directly to the Delta). The diazinon concentrations at this location are affected by inputs from the entire Sacramento Valley, and diazinon loads in the Sacramento River at Sacramento represent the sum of those inputs.

As was shown in Figure A2.2, diazinon levels tend to be highest in the Sacramento River during January and February, coincident with the period of high diazinon use on nut and stonefruit trees during the dormant season, and also coincident with the period of heaviest rainfall in the Sacramento Valley. Higher concentrations in the lower Sacramento and Feather Rivers tend to occur during and immediately after rainfall events, indicating that stormwater runoff is transporting diazinon into surface waters. Figure A4.3 shows diazinon concentrations in the Sacramento River at Sacramento and rainfall for two storms during the dormant spray season in 1994. For both of these storms, the diazinon concentrations in the Sacramento River rose following the start of rainfall events, and fell shortly after the rainfall stopped.

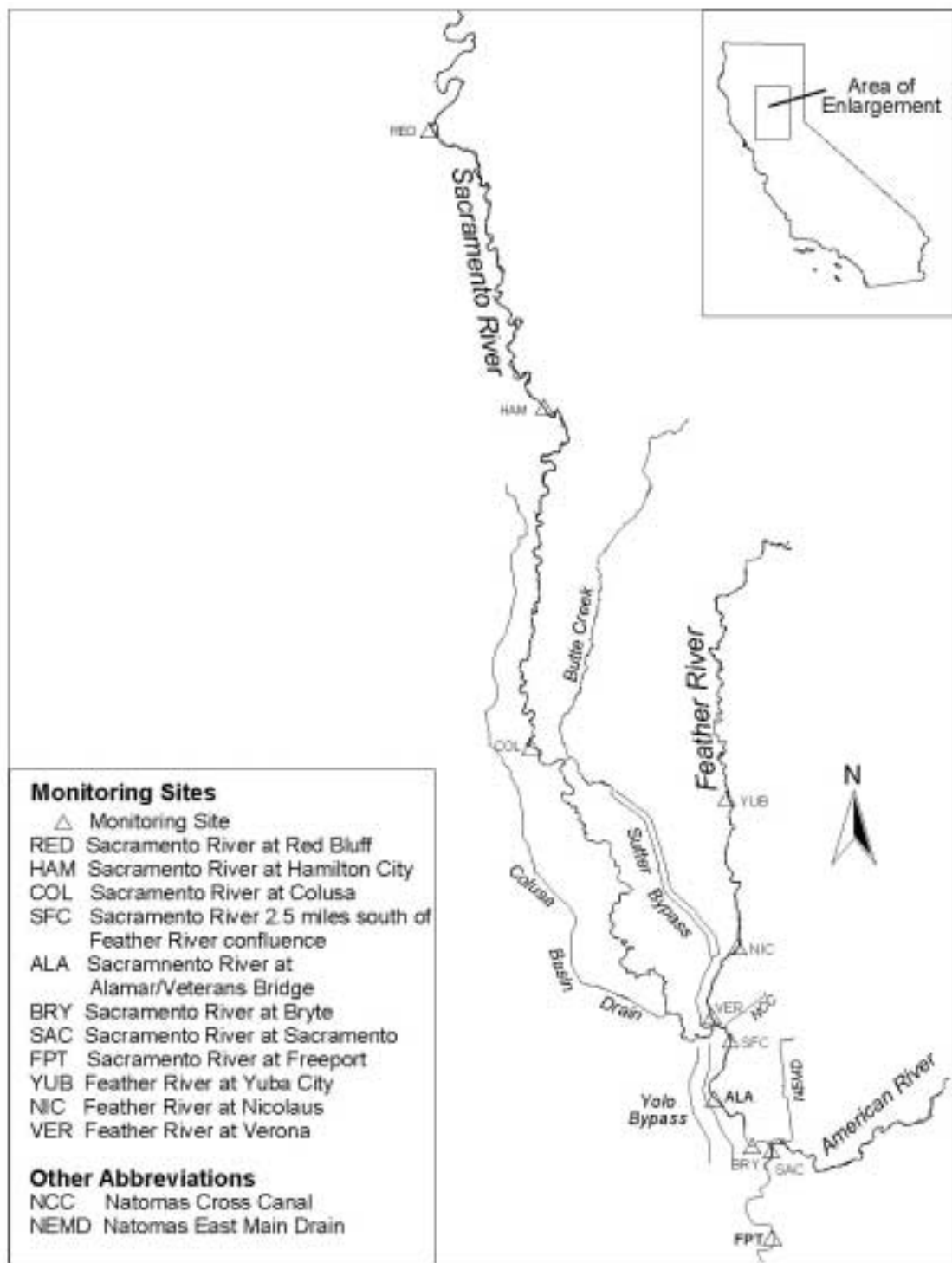


Figure A4.2. Major Diazinon Monitoring Sites on the Lower Sacramento and Feather Rivers

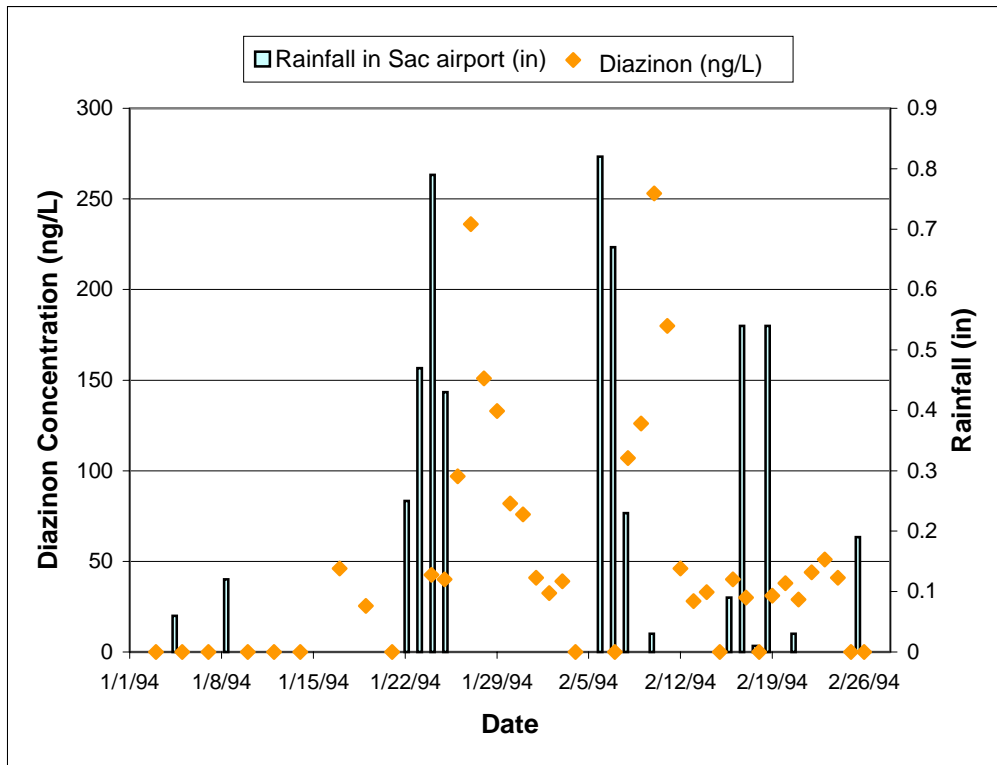


Figure A4.3. Rainfall at Sacramento International Airport and Diazinon Concentration in the Sacramento River at Sacramento during January and February, 1994.

Concentrations in the Sacramento River at Sacramento during January and February of 1992 – 2001 range from no detectable levels to 393 ng/L. Figure A4.4 shows box plots of diazinon concentrations measured in January and February for each year from 1992 through 2001 in which 5 or more concentration data points were available.

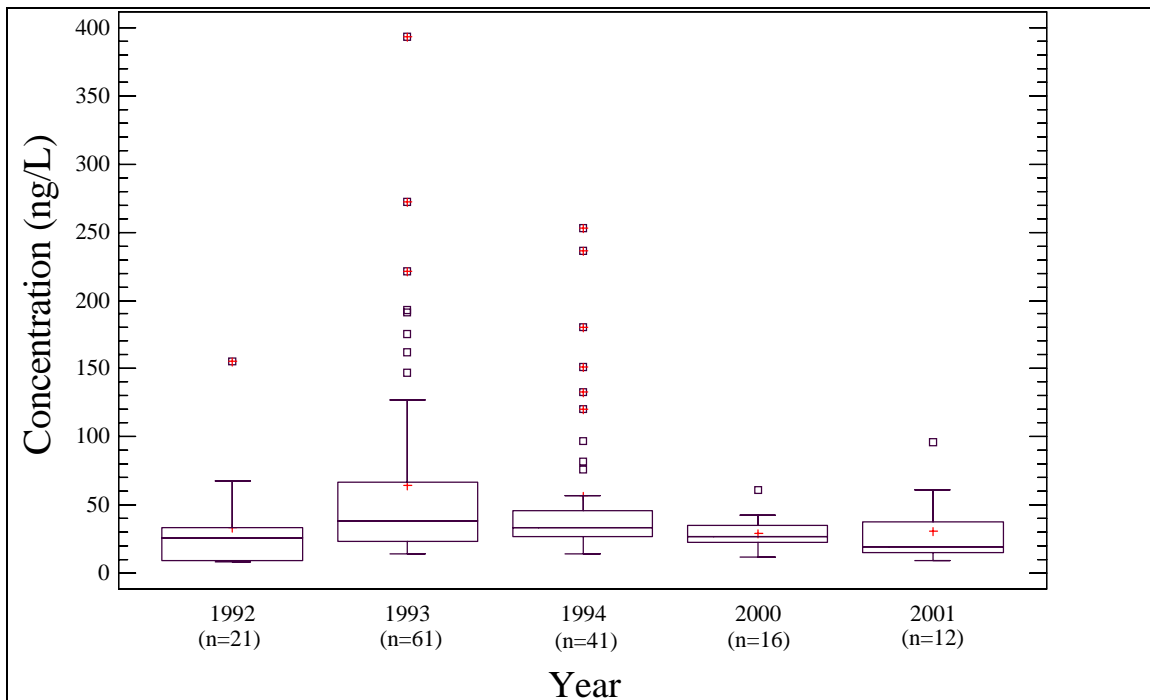


Figure A4.4. Box Plots of Diazinon Concentrations in the Sacramento River at Sacramento in January and February, 1992 - 2001.

See Appendix D for a list of data sources.

[Explanation of the Box Plot: The rectangular part of the plot extends from the lower quartile (25th percentile) to the upper quartile (75th percentile), covering the center half of the data for each year. The center lines within each box show the location of the median sample concentration for each year. The plus signs indicate the location of the yearly means. The whiskers extend from the box to the minimum and maximum values in each year, unless there are any outside or far outside points, which are plotted separately. Outside points are points which lie more than 1.5 times the interquartile range (the range between the 25th and 75th percentile) above or below the box and are shown as small squares. Far outside points are points which lie more than 3.0 times the interquartile range above or below the box and are shown as small squares with plus signs through them.]

The Sacramento River at Alamar is located just upstream of where Veteran's Bridge on Interstate Highway 5 crosses the Sacramento River. This monitoring location is downstream of the inputs of the Feather River, Sacramento Slough, Cross Canal, and Colusa Basin Drain, but upstream of the inputs of the Natomas East Main Drain and the American River. Therefore the diazinon concentrations and loads in the Sacramento River at Alamar represent the inputs of all the Sacramento Valley sub-watersheds except the American River sub-watershed. Concentrations in the Sacramento River at Alamar in January and February of 1998 through 2002 range from less than 5 ng/L to 171 ng/L. Figure A4.5 shows box plots of diazinon concentrations measured in the Sacramento River at Alamar in January and February of 1998 through 2002.

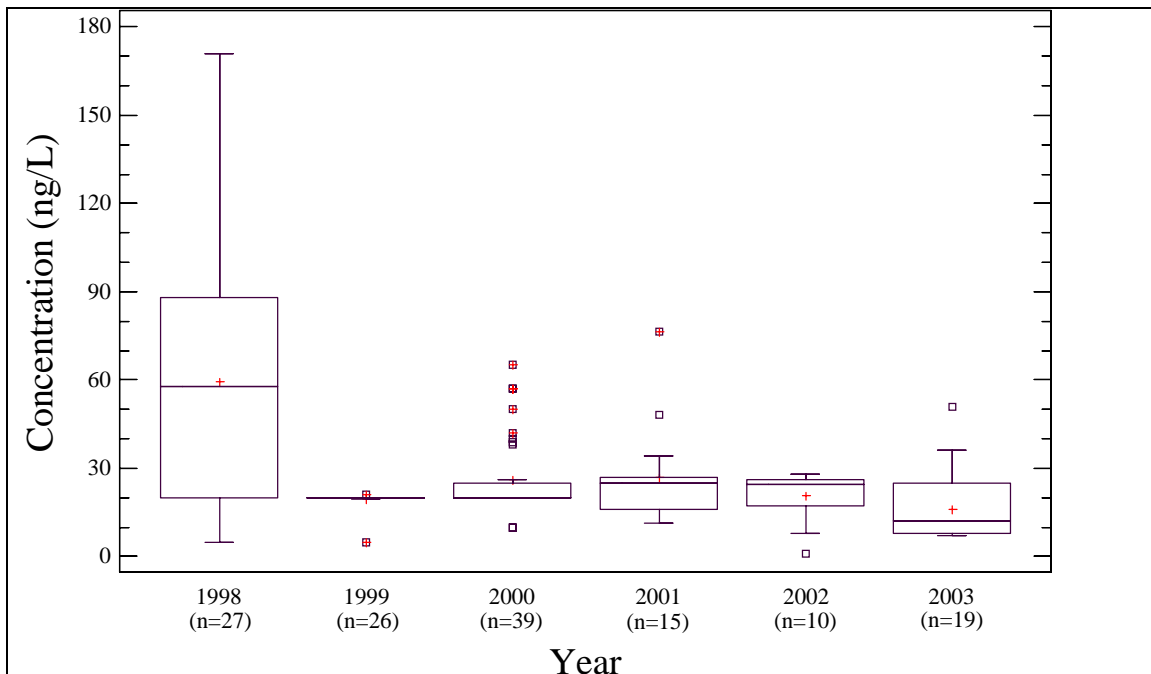


Figure A4.5. Box Plots of Diazinon Concentrations in the Sacramento River at Alamar in January and February, 1998 - 2003. See Appendix D for a list of data sources, and Figure A4.4 for a description of the box plot

Calculated daily diazinon loads in the Sacramento River at Sacramento in January and February of 1992-2001 ranged from approximately 200 grams per day to over 39,000 grams per day. Comparisons from year to year of the total diazinon loads should be done with consideration of the design of the monitoring programs, since the extent and timing of monitoring programs varied from year to year.

Table A4.6. Diazinon Loads in the Sacramento River at the City of Sacramento for January and February of 1992, 1993, 1994, 2000, and 2001

1992		1993		1994		2000*		2001	
Period Monitored	Load in grams	Period Monitored	Load in grams	Period Monitored	Load in grams	Period Monitored	Load in grams	Period Monitored	Load in grams
1/3-2/28	129,100	1/4-2/28	429,700	1/24-1/31 (storm 1)	42,700	1/30-2/3 (storm 1)	17,690*	1/25-1/31 (storm 1)	19,100
				2/7-2/14 (storm 2)	46,300	2/11-2/15 (storm 2)	27,670*	2/10-2/16 (storm 2)	5,900
				2/17-2/23 (storm 3)	14,300	2/21-2/25 (storm 3)	14,970*		
Total	129,100		429,700	Total	103,300		59,870*		25,000

* Information for 2000 is from Dileanis et al., 2002.

A.4.6 Sources by Sub-watershed

A.4.6.1 Lower Feather River Sub-watershed

The Feather River is the largest tributary of the Sacramento River. The lower Feather River flows from Lake Oroville to the confluence with the Sacramento River near Verona. The lower Feather River receives drainage from Honcut Creek, Jack Slough, the Yuba River, and the Bear River, as shown in Figure A4.6. Flow in the lower Feather River is controlled mainly by releases from Lake Oroville and flow from the Yuba River (Domagalski and Dileanis, 2000). The lower Feather River basin contains approximately 15,400 acres of urban land, including the city of Marysville, and approximately 2,000 acres of almonds, 7,900 acres of peaches and 19,130 acres of plums and prunes (DWR, 2001a).

A.4.6.1.1 Diazinon Use in the Lower Feather River Sub-watershed

Reported agricultural dormant season diazinon use in the lower Feather River sub-watershed from 1993 through 2001 is shown in Table A4.5. As indicated in Table A4.5, the lower Feather River sub-watershed accounts for a significant percentage (between 9.6 and 23.6 percent) of all reported Sacramento Valley dormant season agricultural diazinon applications. The approximate locations of these applications can be seen in Figures 1.5 and 1.6 for 1993/1994 through the 2000/2001 dormant spray seasons. It should be noted that the orchards to the west of the Feather River drain west toward the Sutter Bypass, as illustrated by the sub-watershed delineations in Figure A4.1. The majority of the dormant season diazinon applications in the lower Feather River watershed take place on orchards along the Feather River and near Honcut Creek, Jack Slough, the Yuba River and the Bear River.



Figure A4.6. The Lower Feather River Sub-watershed

A.4.6.1.2 Diazinon Concentrations and Loads in the Lower Feather River Basin

Diazinon concentrations in the Feather River near its outlet (at the monitoring stations near Nicolas and Verona) during January and February range from below detection limits to 960 ng/L. Figure A4.7 shows box plots of diazinon concentrations measured in the Feather River near its outlet in January and February of each year from 1994 through 2002 in which 5 or more concentration data points were available.

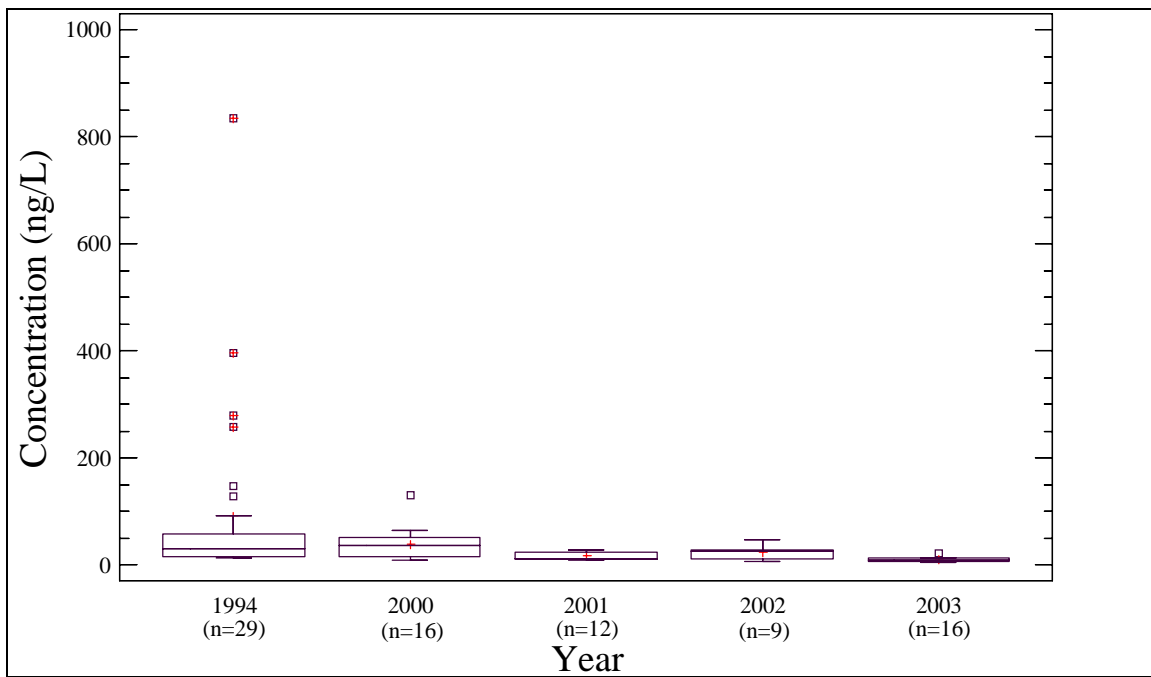


Figure A4.7. Box Plots of Diazinon Concentrations in the Feather River Near its outlet in January and February, 1994 - 2003. See Appendix D for a list of data sources, and Figure A4.4 for a description of the box plot.

Honcut Creek, Jack Slough, and the Bear and Yuba Rivers have all been found to have diazinon concentrations in excess of 80 ng/l during the dormant spray season and are likely to contribute significant diazinon loads to the lower Feather River. The highest diazinon concentrations in the lower Feather River Basin were found in Jack Slough, which had a maximum concentration of 1,490 ng/l. Likely sources to these waterbodies are the dormant season diazinon applications to local orchards, and, in the case of the Yuba River, urban diazinon applications in the Marysville area.

Calculated daily diazinon loads in the Feather River near its outlet in January and February of 1994 -2001 ranged from less than 80 grams per day to over 10,500 grams per day. The total calculated loads for 1994, 2000 and 2001 are shown in Table A4.7. These calculated loads were approximately 21, 26 and 5 percent of the calculated loads for the Sacramento River at the city of Sacramento for 1994, 2000 and 2001, respectively.

Table A4.7. Diazinon Loads in the Feather River Near Its Outlet for January and February of 1994, 2000 and 2001

	1994		2000*		2001	
	Period Monitored	Load in grams	Period Monitored	Load in grams	Period Monitored	Load in grams
Storm 1	1/24-1/31	15,340	1/30-2/3	4,990*	1/24-1/28	710
Storm 2	2/7-2/14	4,650	2/11-2/15	8,160*	2/10-2/14	500
Storm 3	2/17-2/23	1,500	2/21-2/25	3,170*		
Total		21,490		15,880*		1,210
* Information for 2000 is from Dileanis et al., 2002.						

A.4.6.2 Sacramento River Above Colusa

The Sacramento River above Colusa sub-watershed includes all lands draining into the Sacramento River between Keswick Reservoir south to the city of Colusa. Cottonwood Creek, Battle Creek, Mill Creek, Deer Creek, Stony Creek and Big Chico Creek, as well as several other smaller creeks, flow into the Sacramento River in this sub-watershed. This sub-watershed includes approximately 73,850 acres of urban lands, including the cities of Redding, Chico, and Red Bluff. This watershed also includes approximately 44,600 acres of almonds, 24,250 acres of plums (dried and fresh), and 110 acres of peaches. Nearly all of these orchards are located in the southern part of the sub-watershed, south of the city of Red Bluff, along the Sacramento River and near Chico.

A.4.6.2.1 Diazinon Use in the Sacramento Valley Above Colusa

Agricultural dormant season diazinon use in the Sacramento Valley above Colusa sub-watershed from 1993 through 2001 is shown in Table A4.5. As indicated in Table A4.5, this subwatershed receives a significant percentage of all Sacramento Valley dormant season diazinon applications, ranging from 17.5 to 33.3 percent. The approximate locations of these applications can be seen in Figures 1.5 and 1.6 for 1993/1994 through 2000/2001 dormant spray seasons.

A.4.6.2.2 Diazinon Loads and Concentrations in the Sacramento Valley Above Colusa

Diazinon concentrations in the Sacramento River at Colusa during January and February of 1994-2002 ranged from below detection limits to 220 ng/L. Figure A4.8 shows box plots of diazinon concentrations measured in the Sacramento River at Colusa in January and February of each year from 1994 through 2002 in which 5 or more concentration data points were available.

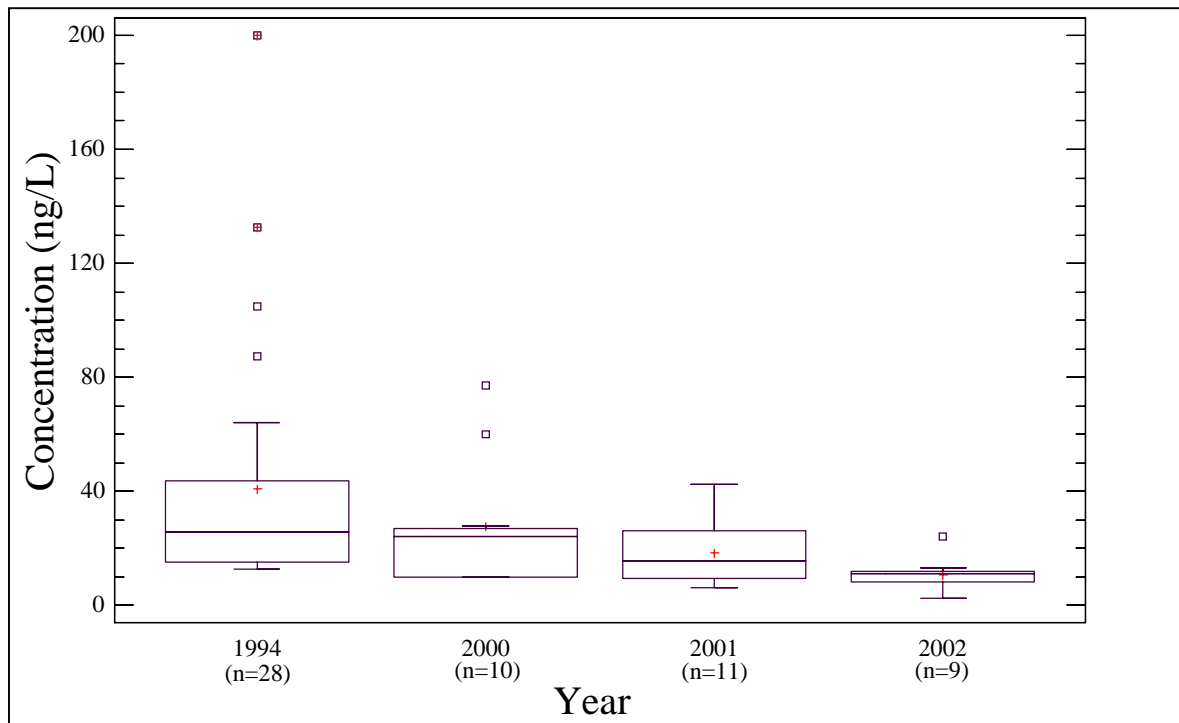


Figure A4.8. Box Plots of Diazinon Concentrations in the Sacramento River at Colusa in January and February, 1994 - 2003. See Appendix D for a list of data sources, and Figure A4.4 for a description of the box plot.

In the 1994 dormant season, diazinon concentrations in excess of 80 ng/L were detected in the Sacramento River at multiple stations along the Sacramento River between Red Bluff and Colusa, including the Sacramento River at Butte City, Ord Bend Bridge, Hamilton City, and Vina (Holmes et al., 2000). In 1994, diazinon was not detected at levels of concern in the Sacramento River north of Red Bluff (Holmes et al., 2000). No subsequent monitoring for diazinon has been done in the Sacramento River north of Colusa. Many of the tributaries that enter the Sacramento River between Red Bluff and Colusa drain large areas of stonefruit and almond orchards. Little diazinon concentration data is available for these tributaries. The high diazinon concentrations in the Sacramento River downstream of these inputs and the proximity of these waterbodies to diazinon application areas indicate that these waterbodies likely contribute significant diazinon loads to the Sacramento River.

Calculated daily diazinon loads in the Sacramento River at Colusa in January and February of 1994 -2001 ranged from less than 100 grams per day to over 9,900 grams per day. The total calculated diazinon loads in January and February of 1994, 2000 and 2001 are shown in Table A4.8. These calculated loads were approximately 35 and 28 percent of the calculated loads for the Sacramento River at the city of Sacramento for 1994 and 2001, respectively.

Table A4.8. Diazinon Loads in the Sacramento River at Colusa for January and February of 1994, and 2001

	1994		2001	
	Period Monitored	Load in Grams	Period Monitored	Load in Grams
Storm1	1/24-1/28	7,270	1/24-1/28	5,460
Storm2	2/7-2/14	19,760	2/10-2/14	1,520
Storm3	2/17-2/23	9,570		
Total		36,600		6,980

A.4.6.3 Colusa Basin Drain

The Colusa Basin Drain sub-watershed includes all the lands located to the west of the Sacramento River that drain into the Colusa Basin Drain. This sub-watershed includes approximately 1,450 acres of urban lands, 36,800 acres of almonds, 6,630 acres of plums (dried and fresh), and 130 acres of peaches. Under normal flow conditions, the Colusa Basin Drain empties into the Sacramento River upstream of Verona, but under high flow conditions, it is diverted into the Yolo Bypass via the Knights Landing Ridge Cut.

A.4.6.3.1 Diazinon Use in the Colusa Basin

Agricultural dormant season diazinon use in the Colusa Basin from 1993 through 2001 is shown in Table A4.5. As indicated in Table A4.5, the Colusa Basin accounts for a significant percentage of all dormant season diazinon applications, ranging from 10 to 28 percent. The locations of these applications can be seen in Figures 1.5 and 1.6 for 1993/1994 through 2000/2001 dormant spray seasons.

A.4.6.3.2 Diazinon Loads and Concentrations in the Colusa Basin Drain

Diazinon concentrations in the Colusa Basin Drain near its outlet during January and February range from below detection limits to 1,020 ng/L. Figure A4.9 shows box plots of diazinon concentrations measured in the Colusa Basin Drain near its outlet in January and February of each year from 1994 through 2002 in which 5 or more concentration data points were available.

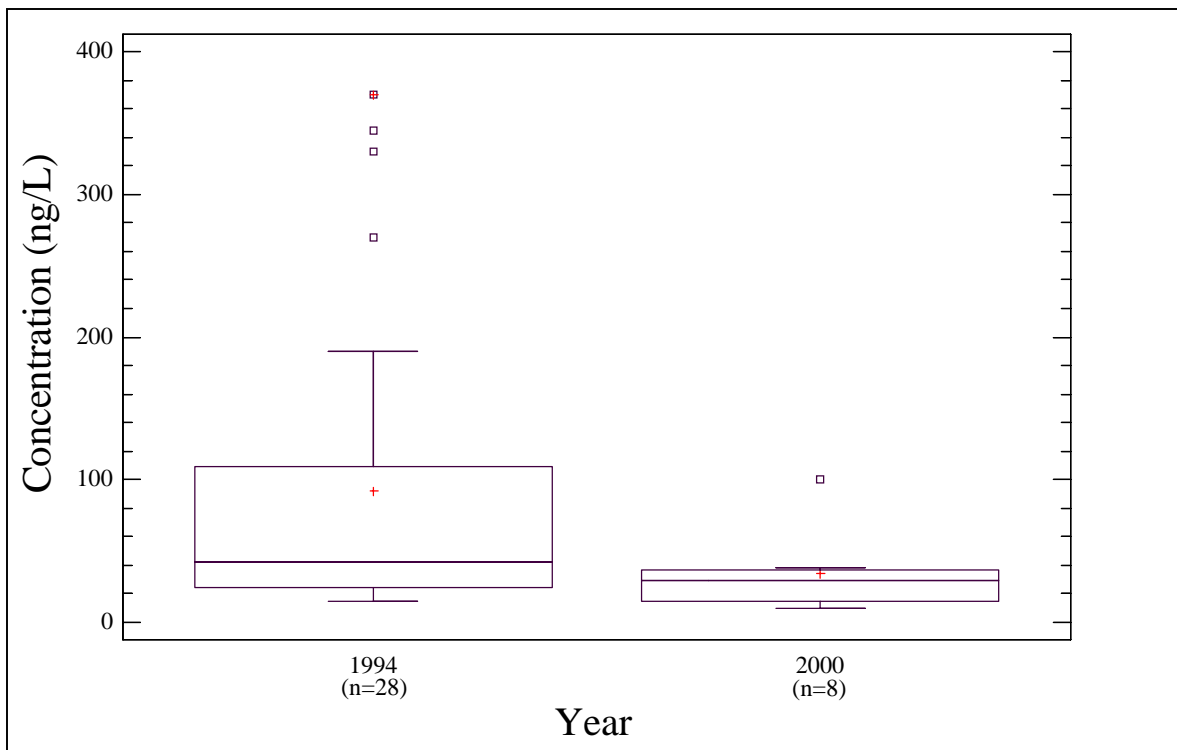


Figure A4.9. Box Plots of Diazinon Concentrations in the Colusa Basin Drain Near its Outlet in January and February, 1994 – 2000. See Appendix D for a list of data sources, and Figure A4.4 for a description of the box plot.

Calculated daily diazinon loads in the Colusa Basin Drain near its outlet in January and February of 1994 -2000 ranged from less than 1 grams per day to over 800 grams per day. The total diazinon load contributed by the Colusa Basin Drain in January and February of 1994 was 4,710 grams, about 5 percent of the total load measured in the Sacramento River at the City of Sacramento during that period.

A.4.6.4 Sutter Basin/Butte Creek

The Sutter Basin/Butte Creek sub-watershed, shown in Figure A4.10, includes areas draining into Butte Creek south of Chico and the areas draining into the Sutter Bypass between the Sacramento and Feather Rivers and south of the Sutter Buttes. The Main Drainage Canal, Cherokee Canal, and a number of other tributaries flow into Butte Creek in the area north of the Sutter Buttes. Butte Creek then flows into Butte Slough, which flows into the Sutter Bypass just south of the Sutter Buttes. Wadsworth Canal, Gilsizer Slough and a number of smaller drains flow into the Sutter Bypass in the Sutter Basin. As a result of efforts to control flooding on the Sacramento River during high flows, water can also flow into the Sutter Bypass through Moulton, Colusa, and Tisdale bypasses. During normal conditions, the Sutter Bypass drains through Sacramento Slough into the Sacramento River near Verona, and therefore the loads at Sacramento Slough are the loads that this sub-watershed contributes to the Sacramento River. During

high flow conditions, the Sacramento Slough becomes submerged and the Sutter Bypass flows directly into the Sacramento River. This sub-watershed includes approximately 25,800 acres of urban lands, including Yuba City. This sub-watershed includes approximately 32,880 acres of almonds, 36,530 acres of plums (dried and fresh), and 13,490 acres of peaches.

A.4.6.4.1 Diazinon Use in the Sutter Basin/Butte Creek Sub-watershed

Agricultural dormant season diazinon use in the Sutter Basin/Butte Creek sub-watershed from 1993 through 2001 is shown in Table A4.5. As indicated in Table A4.5, this sub-watershed accounts for a significant percentage of Sacramento Valley dormant season diazinon applications, ranging from 37.6 to 48.3 percent. The approximate locations of these applications can be seen in Figures 1.5 and 1.6 for 1993/1994 through 2000/2001 dormant spray seasons.

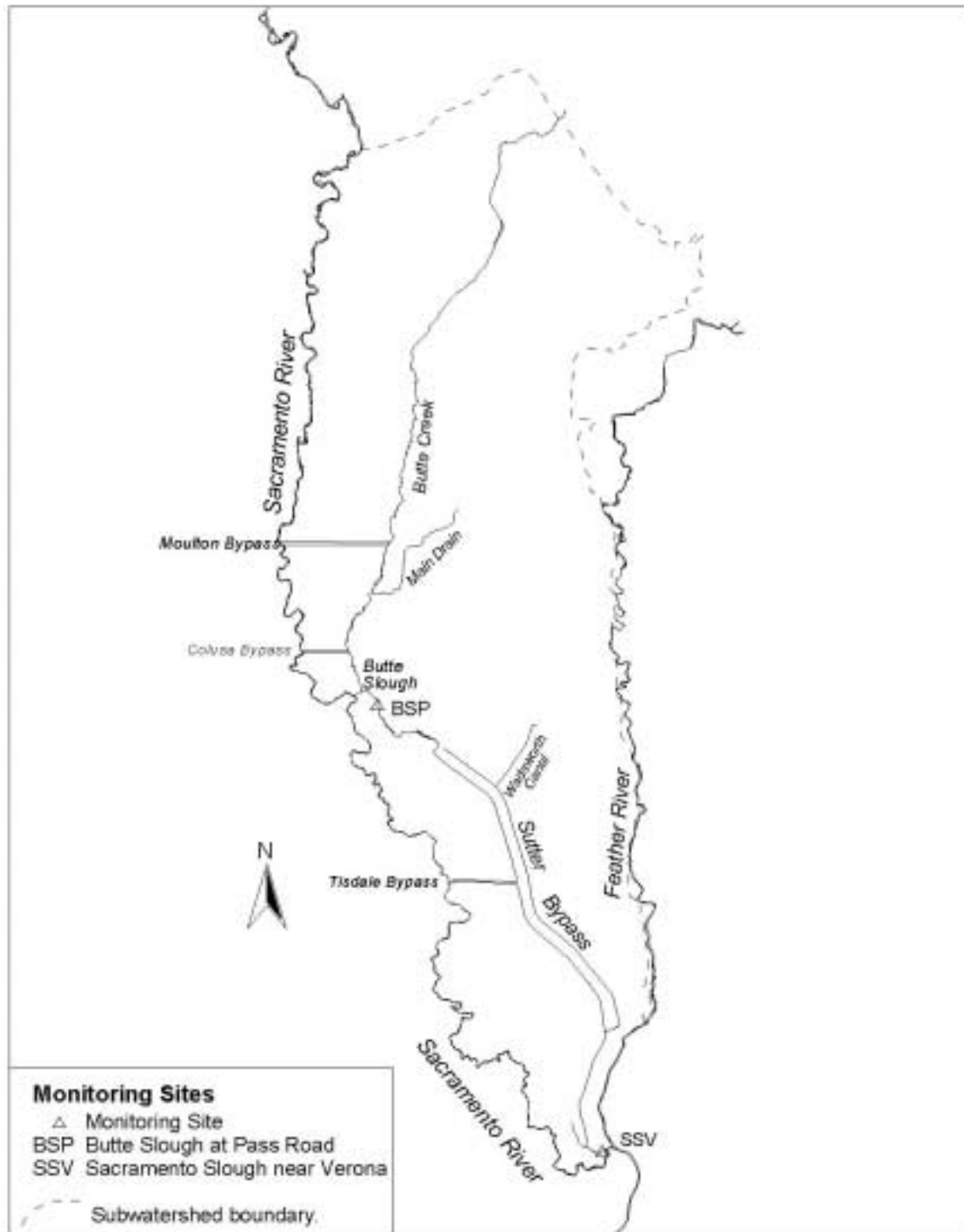


Figure A4.10. Sutter Basin/Butte Creek Sub-watershed

A.4.6.4.2 Diazinon Loads and Concentrations in the Sutter Basin/Butte Creek Sub-watershed

Diazinon concentrations in Sacramento Slough during the dormant spray season range from below detection limits to over 1,900 ng/L. Figure A4.11 shows box plots of diazinon concentrations measured in Sacramento Slough near its outlet in January and February of each year from 1994 through 2002 in which 5 or more concentration data points were available. During storm events in January and February, diazinon concentrations in excess of 1,000 ng/L have been detected in Main Drain, Wadsworth Canal, and the other drains that flow through orchard areas and into Butte Creek and the Sutter Bypass (Dileanis *et al.*, 2002; Holmes *et al.*, 2000).

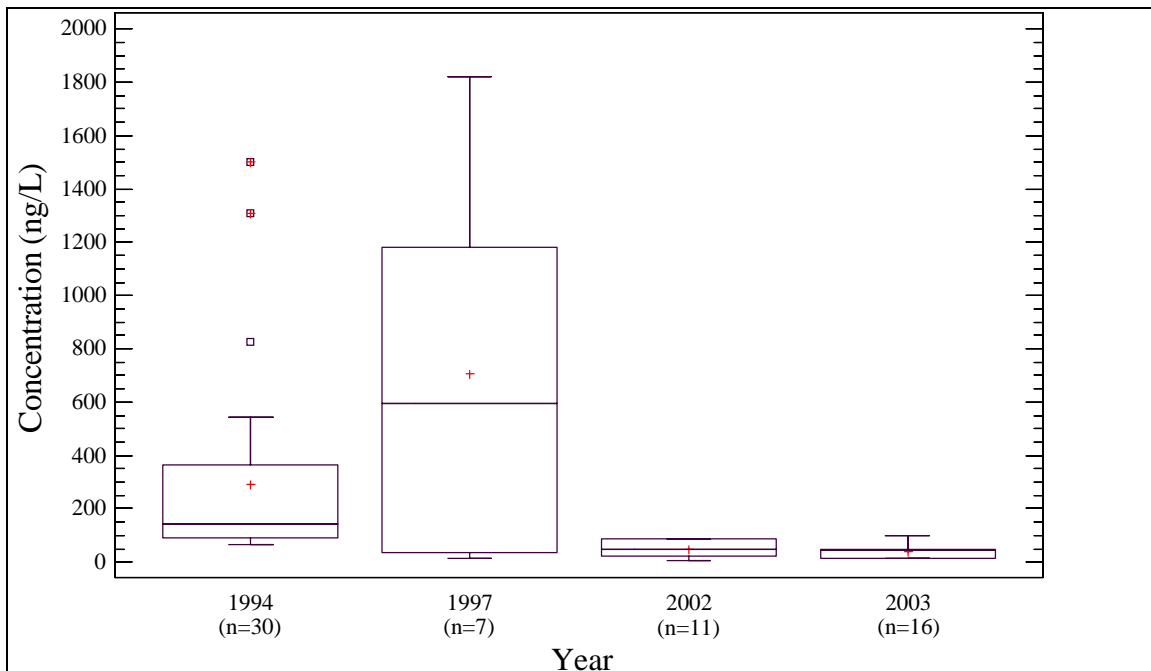


Figure A4.11. Box Plots of Diazinon Concentrations in Sacramento Slough in January and February, 1994-2003. See Appendix D for a list of data sources, and Figure A4.4 for a description of the box plot.

Diazinon loads in Sacramento Slough near its outlet in January and February of 1994 through 2001 ranged from less than 40 grams per day to over 7,300 grams per day. The total estimated diazinon load in January and February of 1994 was 38,890 grams, approximately 38% of the total estimated load in the Sacramento River at Sacramento during that period.

A.4.6.5 Natomas Cross Canal Area

The Cross Canal Area sub-watershed, shown in Figure A4.12, consists of areas of the Feather River's confluence with the Sacramento River and north of the American River

Watershed that drain into the Sacramento River from the east. The Natomas Cross Canal, Natomas West Drainage Canal, and a number of other smaller drains flow into the Sacramento River in this sub-watershed. This sub-watershed includes approximately 18,880 acres of urban lands and approximately 110 acres of almonds, 1,320 acres of plums (dried and fresh), and 202 acres of peaches.

A.4.6.5.1 Diazinon Use in the Natomas Cross Canal Area

Agricultural dormant season diazinon use in the Cross Canal Area from 1993 through 2001 is shown in Table A4.5. As indicated in Table A4.5, the Cross Canal Area receives a very low percentage of Sacramento Valley dormant season diazinon applications, ranging from 0.1 to 1.3 percent. The locations of these applications can be seen in Figures 1.5 and 1.6 for 1993/1994 through 2000/2001 dormant spray seasons.

A.4.6.5.2 Diazinon Loads and Concentrations in the Natomas Cross Canal Area

There have been no measurements of diazinon concentrations in the tributaries entering the Sacramento River in the Cross Canal Area. Due to the relatively low percentage of reported diazinon use in this sub-watershed, the diazinon loads it contributes are likely to be far less significant than the loads contributed by any of the other five sub-watersheds.

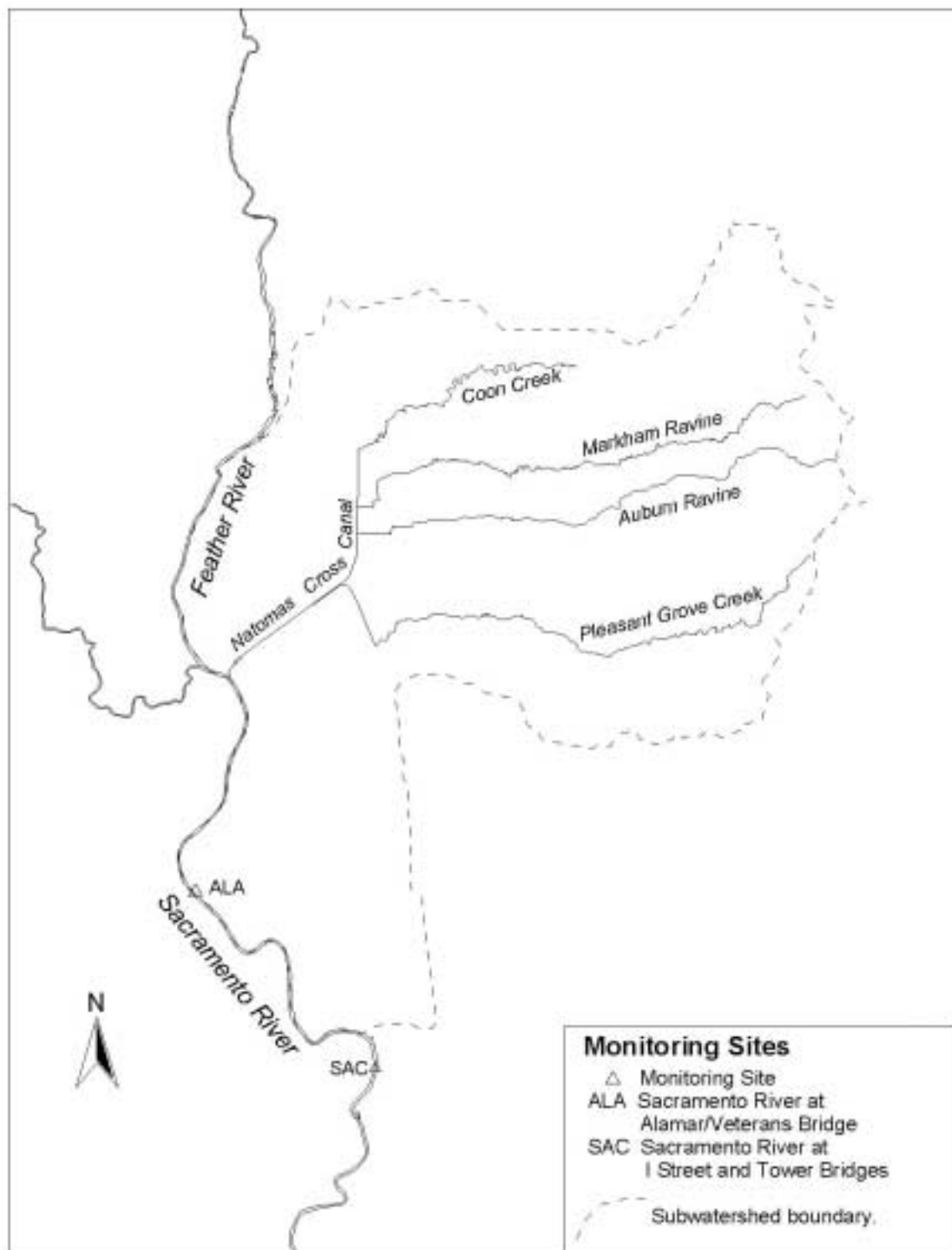


Figure A4.12. Natomas Cross Canal Area Sub-watershed

A.4.6.6 Lower American River Watershed

The lower American River watershed, shown in Figure A4.13, includes areas draining into the lower American River and Natomas East Main Drainage Canal. Dry Creek and Arcade Creek and a number of smaller tributaries flow into the Natomas East Main Drainage Canal north of the American River. During normal flow conditions, the Natomas East Main Drainage Canal flows into the Sacramento River just north of the American River, but during high winter flow events the Natomas East Main Drainage Canal merges with the American River before entering the Sacramento River. Strong Ranch Slough, Chicken Ranch Slough and a number of smaller creeks, drains and sumps discharge to the lower American River. This watershed is predominantly urban in nature, with approximately 110,400 acres of urban lands, including the cities of Roseville, Folsom, Citrus Heights, North Highlands, Carmichael and North Sacramento. This sub-watershed includes approximately 230 acres of almonds, 80 acres of plums (dried and fresh), and 30 acres of peaches.

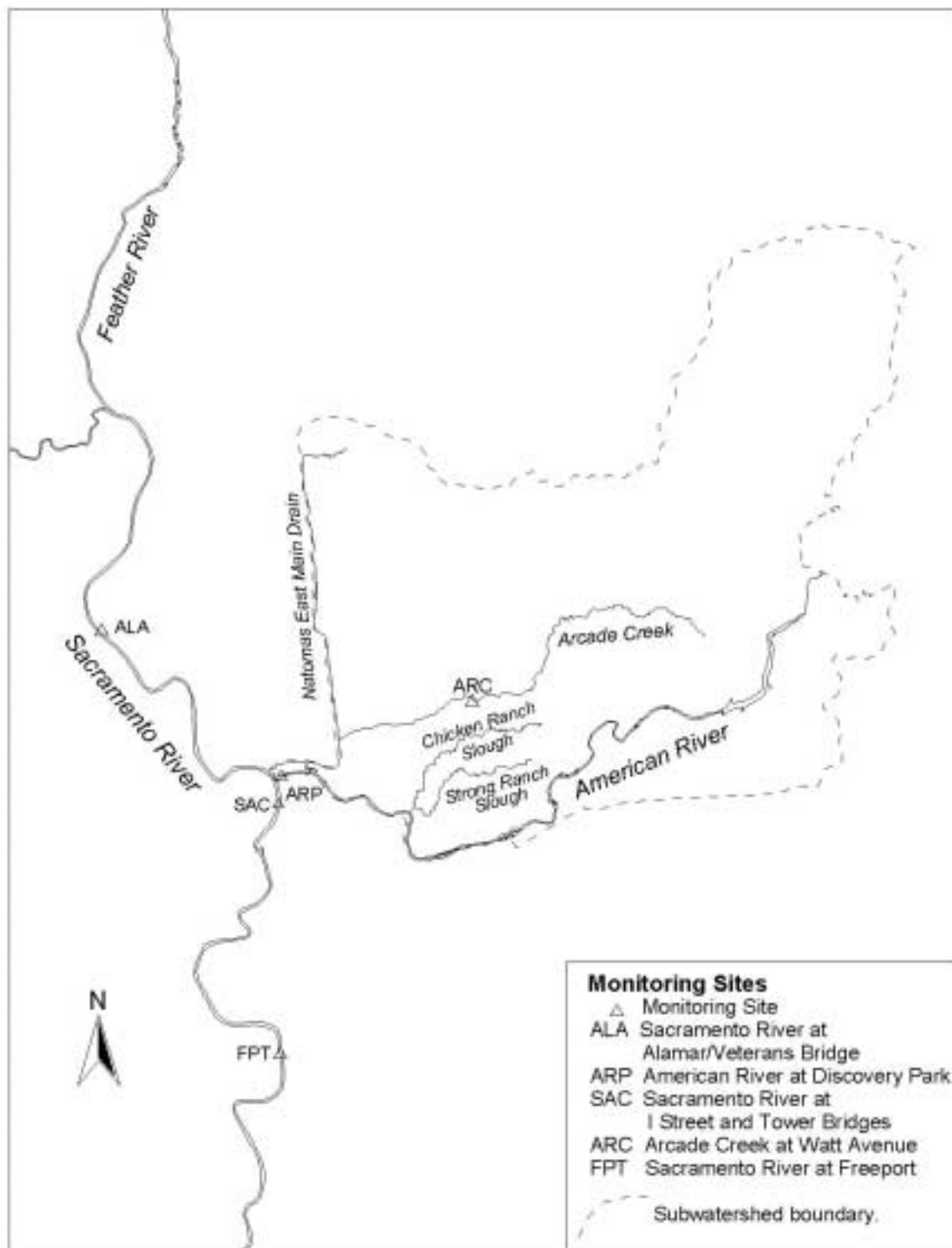


Figure A4.13. Lower American River Watershed

A.4.6.6.1 Diazinon Use in the Lower American River Watershed

Agricultural dormant season diazinon use in the Lower American River watershed from 1993 through 2001 is shown in Table A4.5. As indicated in Table A4.5, the American River watershed receives an extremely small percentage of all dormant season agricultural diazinon applications. Due to the large amount of urban area, this sub-watershed historically received a relatively large amount of diazinon applications from unreported home applications, as well as structural pest control and landscaping maintenance uses, which are reported on a countywide basis.

A.4.6.6.2 Diazinon Loads and Concentrations in the Lower American River Watershed

Diazinon concentrations in the lower American River during January and February of 1997 through 2002 ranged from below detection limits to 100 ng/L, although only 10 measurements were available. Diazinon was detected in half of the samples collected. Calculated daily diazinon loads in the American River near its outlet in January and February of 1997 -2002 ranged from less than 50 grams per day to over 4,100 grams per day.

While there is little available diazinon concentration data for the Natomas East Main Drainage Canal, one of its main tributaries, Arcade Creek, has been extensively sampled in recent years (Domagalski, 2000; Russick, 2001, Denton, 2001). Arcade Creek drains mostly urban areas northeast of the city of Sacramento. The diazinon concentrations in Arcade Creek at Watt Avenue (the location where the greatest amount of data is available) ranged from 81 to 1,390 ng/L. Diazinon loads in Arcade creek at Watt Avenue range from less than 2 grams per day to over 1,900 grams per day (Denton, 2001). During the period of the most intensive study, from May 1999 through May 2000 (Russick, 2001), dry weather diazinon loads calculated at this site were generally negligible, at values of less than 2 grams (0.004 pounds) per day but loads during rainfall events ranged from 6 to 660 grams (0.01 to 1.4 pounds) per day and averaged 296 grams (0.6 pounds) per day.

Diazinon concentrations in excess of 80 ng/L have been detected in many sumps and streams that drain urban areas in the lower American River watershed and flow into the American River or the Natomas East Main Drainage Canal (Russick, 2001, Denton, 2001). Concentrations of diazinon measured in rainfall in the Sacramento area in 1999 and 2000 ranged from 42 to 678 ng/L (Russick, 2001). Because rainfall on impervious surfaces is more likely to become runoff, this rainfall may contribute a portion of the diazinon loads observed in streams in the lower American River watershed.

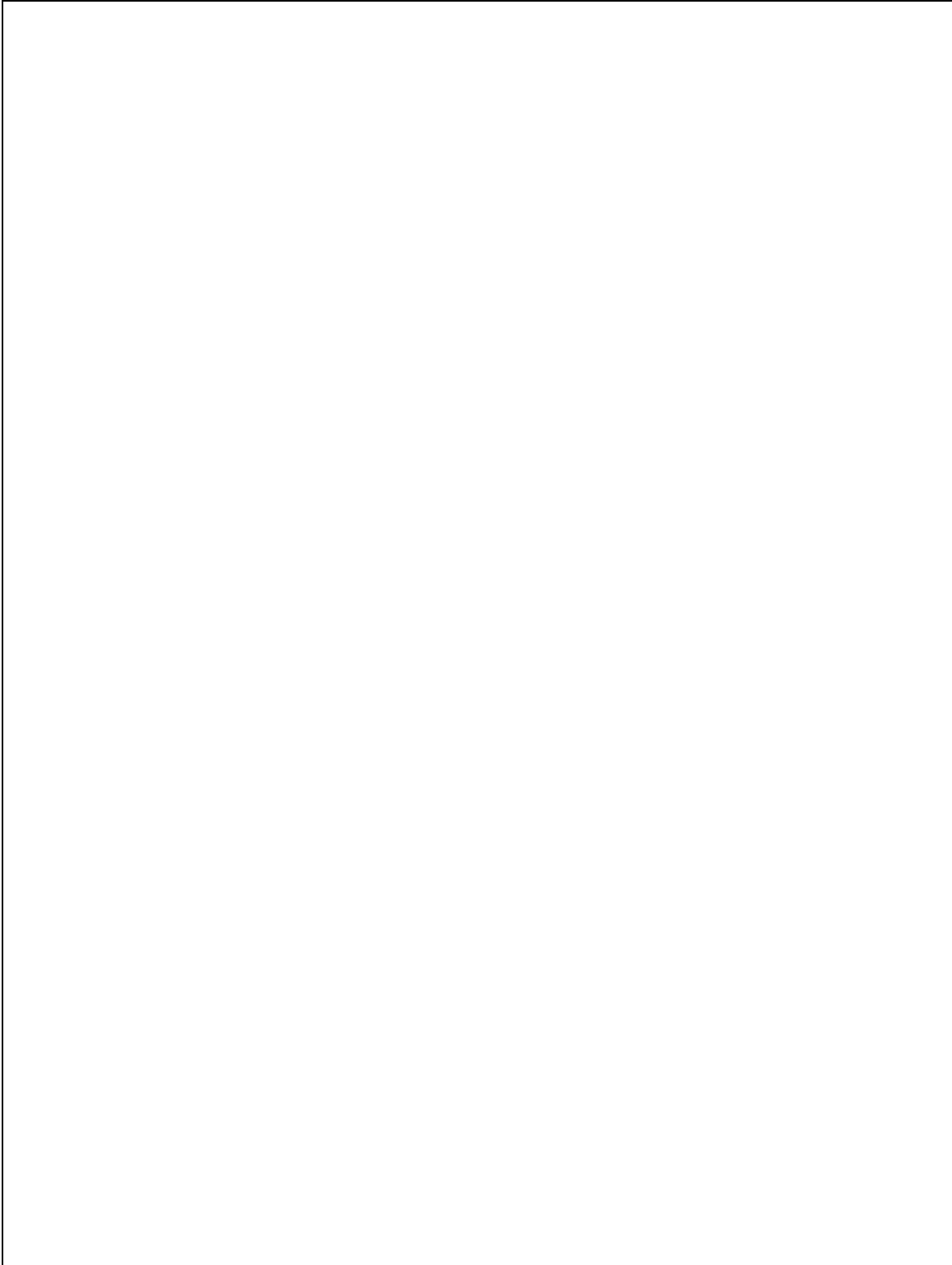
A.4.7 Sources by Land Use

There is currently not enough data to quantify the diazinon loads contributed by different land uses in this large and heterogeneous watershed. Based on the diazinon use, concentration, and loading data described above, however, it appears likely that the applications to urban areas and orchards of almonds, peaches and dried and fresh plums are the most significant sources of diazinon in the lower Sacramento and Feather Rivers during January and February. These land uses received nearly all of reported the Sacramento Valley diazinon applications during the dormant season for the period examined. During storm events in the January and February, elevated concentrations of diazinon are frequently detected in waterbodies that drain sub-watersheds that include significant areas of one or more of these land uses.

A.5 Linkage Analysis

The linkage analysis provides the basis for determining how much diazinon the lower Sacramento and Feather Rivers can assimilate and still meet water quality objectives. These quantities are referred to as the loading capacities of the lower Sacramento and Feather Rivers for diazinon. Once determined, the loading capacities are used to allocate the allowable diazinon loads among the sources of diazinon to the lower Sacramento and Feather Rivers, such that the total of these loads will not result in exceedances of water quality objectives.

Figure A5.1 Shows the locations at which loading capacities are determined for the Sacramento and Feather Rivers. Loading capacities for the lower Sacramento and Feather Rivers are determined near their outlets; the Sacramento River at the city of Sacramento, where the Sacramento River enters the Delta, and the Feather River near Nicolaus, just upstream of where it meets the Sacramento River. Loading capacities are also determined at the Sacramento River at Colusa and at the Sacramento River at Verona.



**Figure A5.1. Sites at which Diazinon Loading Capacities are
Determined for the Sacramento and Feather Rivers**

The Sacramento River at the city of Colusa was chosen to define the loading capacities of the reach of the Sacramento River between Red Bluff and Colusa because the river at this location contains the runoff from a significant portion of the potential diazinon sources in the Sacramento River above Colusa sub-watershed; the flows in the Sacramento River above Colusa are significantly less than those at Sacramento or Verona; and this location has a currently operated flow gauge and an extensive flow record.

The Sacramento River at Verona was chosen to define the loading capacities of the reach of the Sacramento River between Colusa and Verona because it is downstream of where the Colusa Basin Drain, Sacramento Slough, the Feather River, and the Natomas Cross Canal all enter the Sacramento River, and therefore it contains the runoff from nearly all the agricultural sources of diazinon to the Sacramento River; the flows in the Sacramento River at Verona are significantly less than the flows at Sacramento; and the Sacramento River at Verona has a currently operated flow gauge and an extensive flow record.

A.5.1 Assumptions

For purposes of preparing the linkage analysis, certain assumptions need to be made with respect to how the diazinon numeric water quality objective will be established. The characteristics of the numeric targets that affect the loading capacity calculations are: 1) the concentration level(s) established; and 2) the averaging period to assess compliance with the concentration level(s). As discussed in the numeric target section, the numeric targets used in this TMDL are the recommended water quality objectives (see the Basin Plan Staff Report). These criteria are used in calculating the loading capacity.

Compliance with the acute criteria will likely be determined by monitoring no more frequently than daily. Mean daily flow can, therefore, be evaluated to determine daily loading capacities. Diazinon is assumed to be conservative over the time scale being evaluated (e.g. no degradation or transformation).

Since the loading capacity is only evaluated at four sites in the Sacramento and Feather Rivers, it is assumed that if the loading capacities are met at these downstream points, the water quality objectives will be met in the mainstem river reaches of the Sacramento and Feather Rivers upstream of these four sites. These sites are located relatively close downstream from the potential sources areas: no major tributaries significantly dilute diazinon concentrations between the expected diazinon sources and these sites. Therefore, the diazinon concentrations at these sites are expected to be greater than or equal to the concentrations in the reaches upstream of these sites.

A.5.2 Methodology for Determining Loading Capacities

Determination of a loading capacity requires an estimate of the volume of water or the amount of flow available to assimilate the pollutant load. Given an allowable

concentration in the receiving water, the loading capacity, or allowable load, can be determined by finding the product of flow and the target concentration:

Equation A2:

$$\text{Loading Capacity (Mass/Time)} = \text{Flow (Volume/Time)} \times \text{Target Concentration (Mass/Volume)}$$

Variable loading capacities are determined by utilizing daily flow rates for the flow term in Equation A2¹. When calculating the variable loading capacity, a unit conversion factor is applied to yield results in terms of a mass of diazinon that can be assimilated over a day, as shown in equation three.

Equation A3: $LC_v = Q \times C_{wqc} \times f$

Where,

LC_v = variable loading capacity, grams/day or 4-day average grams/day

Q = flow (1-day or 4-day average), cfs

C_{wqc} = numeric target concentration for diazinon, ng/L (1-day or 4-day average)

f = unit conversion factor, 0.002446

For any site on the lower Sacramento or Feather River, if the daily diazinon loads and four-day average diazinon loads are less than the daily and four-day variable loading capacities, respectively, then the numeric target concentrations are expected to be met.

A.5.3 Comparison of Loading Capacities to Current Loads

Tables A5.1, A5.2, A5.3, and A5.4 show recent dormant season daily diazinon loads and the variable daily loading capacities (calculated using the acute criteria) for the Sacramento River at Sacramento, Verona and Colusa and the Feather River near Nicolaus. The daily diazinon loads infrequently exceeded the variable daily loading capacities. Figures A5.2, A5.3, A5.4 and A5.5 show the daily excess loading capacity (determined by subtracting the actual daily loading from the daily loading capacity) available during these recent storm events.

¹ Previous drafts of this TMDL report (Karkoski et al., 2003 - Appendix A, McClure et al., 2002) also contained an alternative method for defining the loading capacities using non-variable “design loading capacities” based on historical flow data. This appendix provides detail on the basis for the recommendations in the Staff Report. The rationale for the selection of the proposed method of determining the loading capacity is contained in the Staff Report.

Table A5.1. Recent Dormant Season Daily Diazinon Loads and Variable Loading Capacities for the Sacramento River at Sacramento.

	Date	Diazinon Concentration (ng/L)	Daily Average Flow (cfs)	Loading Rate* (g/day)	Variable Loading Capacity** (g/day)
Year 2000, Storm #1 (2/1 - 2/5)	2/1/00	29	44700	3171	8749
	2/2/00	61	44400	6626	8690
	2/3/00	41	43800	4394	8573
	2/4/00	38	43400	4035	8495
	2/5/00	24	41900	2460	8201
Year 2000, Storm#2 (2/11 - 2/17)	2/11/00	25	37100	2269	7261
	2/12/00	24	45600	2678	8925
	2/13/00	28	57000	3905	11156
	2/14/00	29	75700	5371	14816
	2/15/00	32	87700	6866	17165
	2/16/00	43	87500	9205	17126
	2/17/00	26	87000	5534	17028
Year 2000, Storm #3 (2/22 - 2/25)	2/22/00	12	72300	2123	14151
	2/23/00	19	74500	3463	14582
	2/24/00	20	75700	3704	14816
	2/25/00	21	75500	3879	14777
Year 2001, Storm #1 (1/25 - 1/31)	1/25/01	18	14700	647	2877
	1/26/01	20	19800	969	3875
	1/27/01	45	25400	2796	4971
	1/28/01	96	28900	6788	5656
	1/29/01	61	26300	3925	5148
	1/30/01	45.5 interpolated	22400	2494	4384
	1/31/01	30	19700	1446	3856
Year 2001, Storm #2 (2/10 - 2/16)	2/10/01	9	13000	286	2544
	2/11/01	11	14400	387	2818
	2/12/01	14	19700	675	3856
	2/13/01	16	23600	924	4619
	2/14/01	28	23700	1624	4639
	2/15/01	23 interpolated	21600	1215	4228
	2/16/01	18	18400	810	3601

* Daily diazinon loads are calculated using equation A1.

** Variable loading capacities are calculated using equation A3.

interpolated - the concentration value used in the loading rate calculations was estimated using linear interpolation between the previous day's and next day's concentration value.

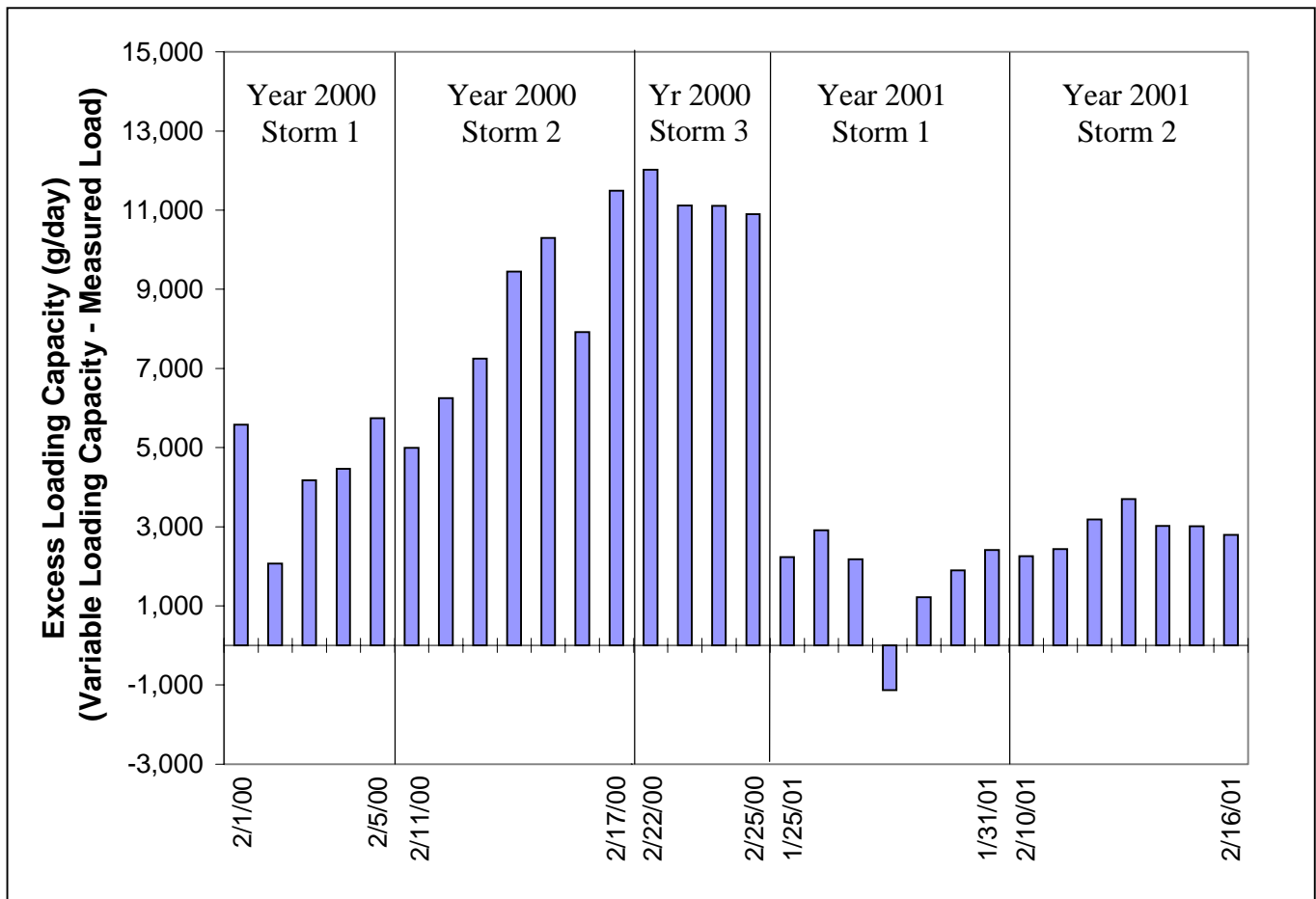


Figure A5.2. Excess Daily Loading Capacity in the Sacramento River at Sacramento During Recent January and February Storms

Table A5.2 Recent Dormant Season Daily Diazinon Loads and Variable Loading Capacities for the Sacramento River at Verona.

	Date	Diazinon Concentration at Alamar (ng/L)	Daily Average Flow (cfs)	Loading Rate* (g/day)	Variable Loading Capacity** (g/day)
Year 2000, Storm #1 (1/30 - 2/2)	1/30/00	25	32600	1994	6381
	1/31/00	25	35000	2141	6850
	2/1/00	38	37200	3458	7281
	2/2/00	61	37400	5582	7320
Year 2000, Storm#2 (2/11 - 2/15)	2/11/00	25	32200	1969	6302
	2/12/00	39	40000	3817	7829
	2/13/00	40	48300	4727	9454
	2/14/00	42	59900	6155	11724
	2/15/00	50	65800	8049	12879
Year 2000, Storm #3 (2/21 - 2/24)	2/21/00	23	61400	3455	12018
	2/22/00	10bdt	60700	1485	11881
	2/23/00	10bdt	62800	1536	12292
	2/24/00	22	64100	3450	12546
Year 2001, Storm #1 (1/24 - 1/29)	1/24/01	20	12800	626	2505
	1/25/01	26	13500	859	2642
	1/26/01	16	19400	759	3797
	1/27/01	39	25200	2404	4932
	1/28/01	76.5	26100	4885	5108
	1/29/01	48	22800	2678	4463
Year 2001, Storm #2 (2/9 - 2/14)	2/9/01	13	11100	353	2173
	2/10/01	13	11600	369	2270
	2/11/01	22	13200	710	2584
	2/12/01	20.5	18600	933	3641
	2/13/01	21	21900	1125	4286
	2/14/01	27	21100	1394	4130
Year 2002, Storm #1 (1/27 - 1/31)	1/27/02	26	18000	1145	3523
	1/28/02	28	18100	1240	3543
	1/29/02	24	17600	1033	3445
	1/30/02	28	17100	1171	3347
	1/31/02	24	16700	981	3269

* Daily diazinon loads are calculated using equation A1. Concentrations for the Sacramento River at Alamar were used to estimate the daily loads at Verona.

** Variable loading capacities are calculated using equation A3.

interpolated - the concentration value used in the loading rate calculations was estimated using linear interpolation between the previous day's and next day's concentration value.

Table A5.2 (Continued) Recent Dormant Season Daily Diazinon Loads and Variable Loading Capacities for the Sacramento River at Verona.

	Date	Diazinon Concentration at Alamar (ng/L)	Daily Average Flow (cfs)	Loading Rate* (g/day)	Variable Loading Capacity** (g/day)
Year 2003, Storm #1 (1/11 - 1/15)	1/11/03	12	29538	867	5781
	1/12/03	7	32688	560	6398
	1/13/03	10	34583	846	6769
	1/14/03	9	38979	858	7629
	1/15/03	10	45962	1124	8996
Year 2003, Storm #2 (2/13 - 2/24)	2/13/03	17	26387	1097	5165
	2/14/03	12	29025	852	5681
	2/15/03	8	30417	595	5953
	2/16/03	7	31788	544	6222
	2/17/03	8	36450	713	7134
	2/18/03	51	39404	4917	7712
	2/19/03	36	39026	3437	7638
	2/20/03	18	37688	1660	7377
	2/21/03	12	37162	1091	7274
	2/22/03	10 interpolated	36462	892	7137
	2/23/03	8	35321	691	6913
	2/24/03	8	34142	668	6682

* Daily diazinon loads are calculated using equation A1. Concentrations for the Sacramento River at Alamar were used to estimate the daily loads at Verona.

** Variable loading capacities are calculated using equation A3.

interpolated - the concentration value used in the loading rate calculations was estimated using linear interpolation between the previous day's and next day's concentration value.

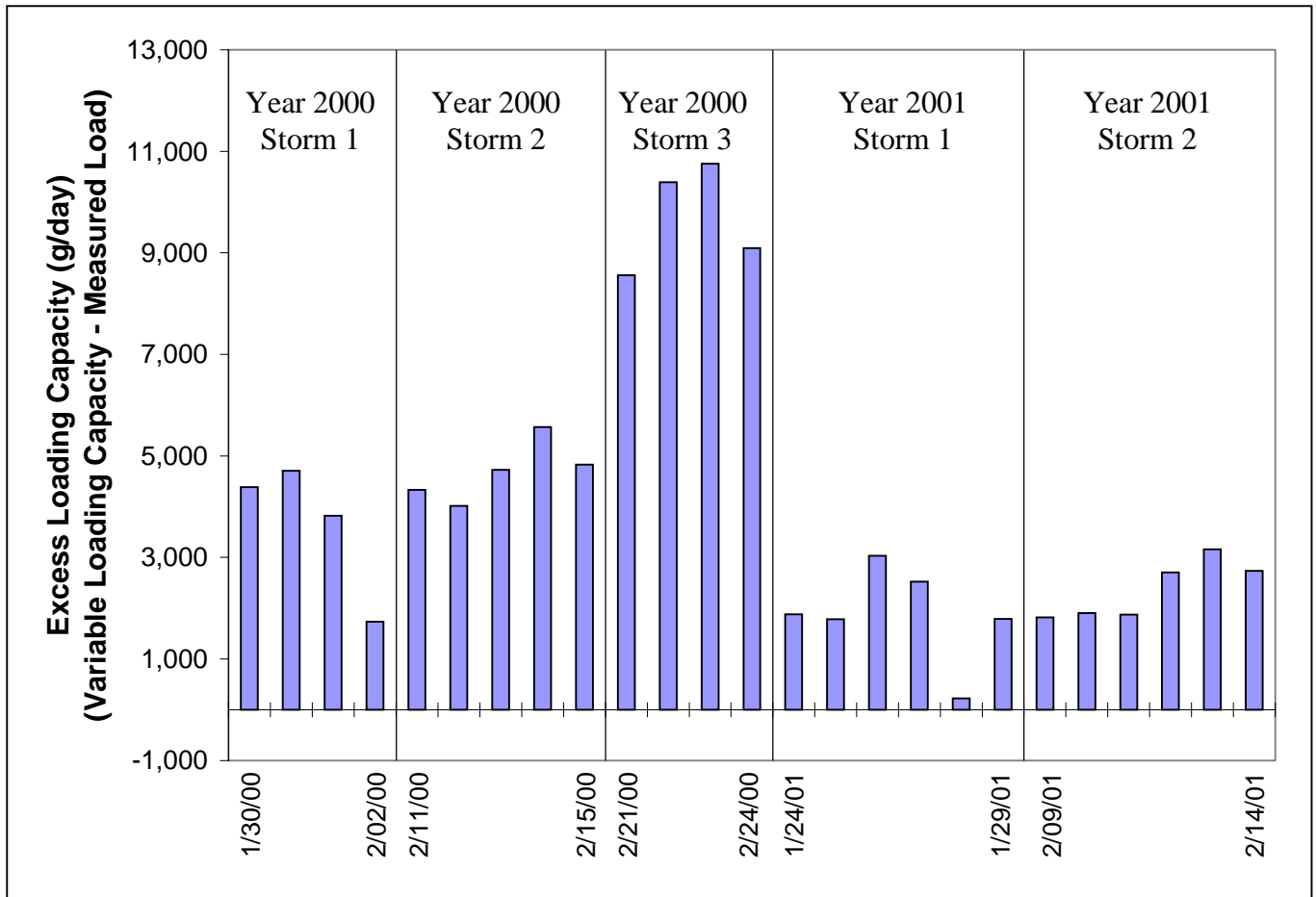


Figure A5.3. Excess Daily Loading Capacity in the Sacramento River at Verona During Recent January and February Storms

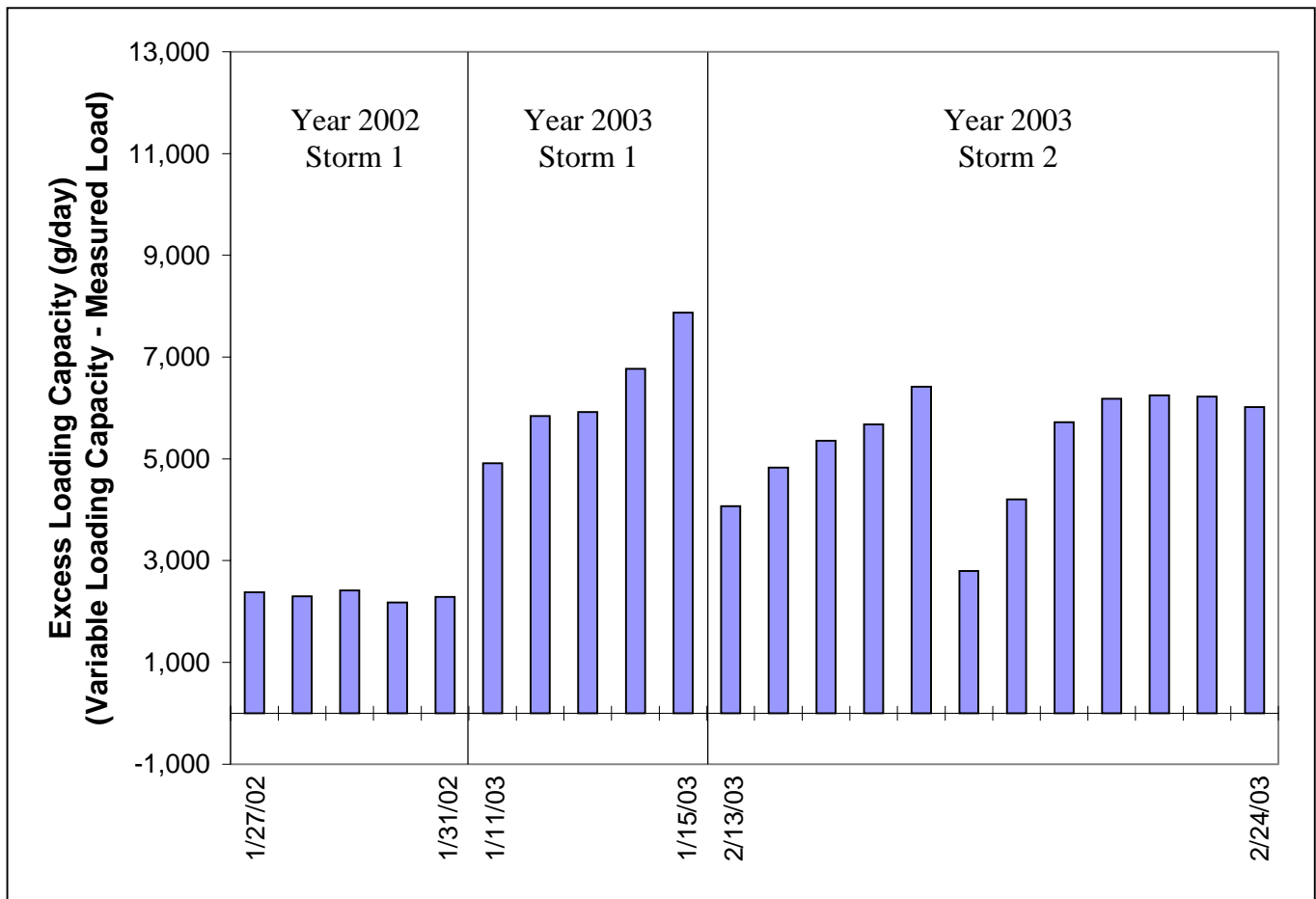


Figure A5.3 (Continued). Excess Daily Loading Capacity in the Sacramento River at Verona During Recent January and February Storms

Table A5.3. Recent Dormant Season Daily Diazinon Loads and Variable Loading Capacities for the Sacramento River at Colusa

	Date	Diazinon Concentration (ng/L)	Daily Average Flow (cfs)	Loading Rate* (g/day)	Variable Loading Capacity** (g/day)
Year 2000, Storm #1 (1/30 - 2/1)	1/30/00	10bdt	21900	536	4286
	1/31/00	77	27900	5256	5461
	2/1/00	60	30800	4521	6028
Year 2000, Storm #2 (2/11 - 2/13)	2/11/00	10bdt	25100	614	4913
	2/12/00	23	33100	1863	6479
	2/13/00	27	37300	2464	7301
Year 2001, Storm #1 (1/24 - 1/28)	1/24/01	15.5	6000	228	1174
	1/25/01	13	12600	401	2466
	1/26/01	35	17900	1533	3503
	1/27/01	42.5	22100	2298	4326
	1/28/01	26	15800	1005	3092
Year 2001, Storm #2 (2/10 - 2/14)	2/10/01	6.25	6280	96	1229
	2/11/01	8.5	10100	210	1977
	2/12/01	17.5	13900	595	2721
	2/13/01	9.5	14000	325	2740
	2/14/01	10	12000	294	2349
Year 2002, Storm #1 (1/27 - 1/31)	1/27/02	11	10300	277	2016
	1/28/02	12	10600	311	2075
	1/29/02	24	10400	611	2036
	1/30/02	12	10000	294	1957
	1/31/02	8	9650	189	1889

* Daily diazinon loads are calculated using equation A1. Concentrations for the Sacramento River at Alamar were used to estimate the daily loads at Verona.

** Variable loading capacities are calculated using equation A3.

interpolated - the concentration value used in the loading rate calculations was estimated using linear interpolation between the previous day's and next day's concentration value.

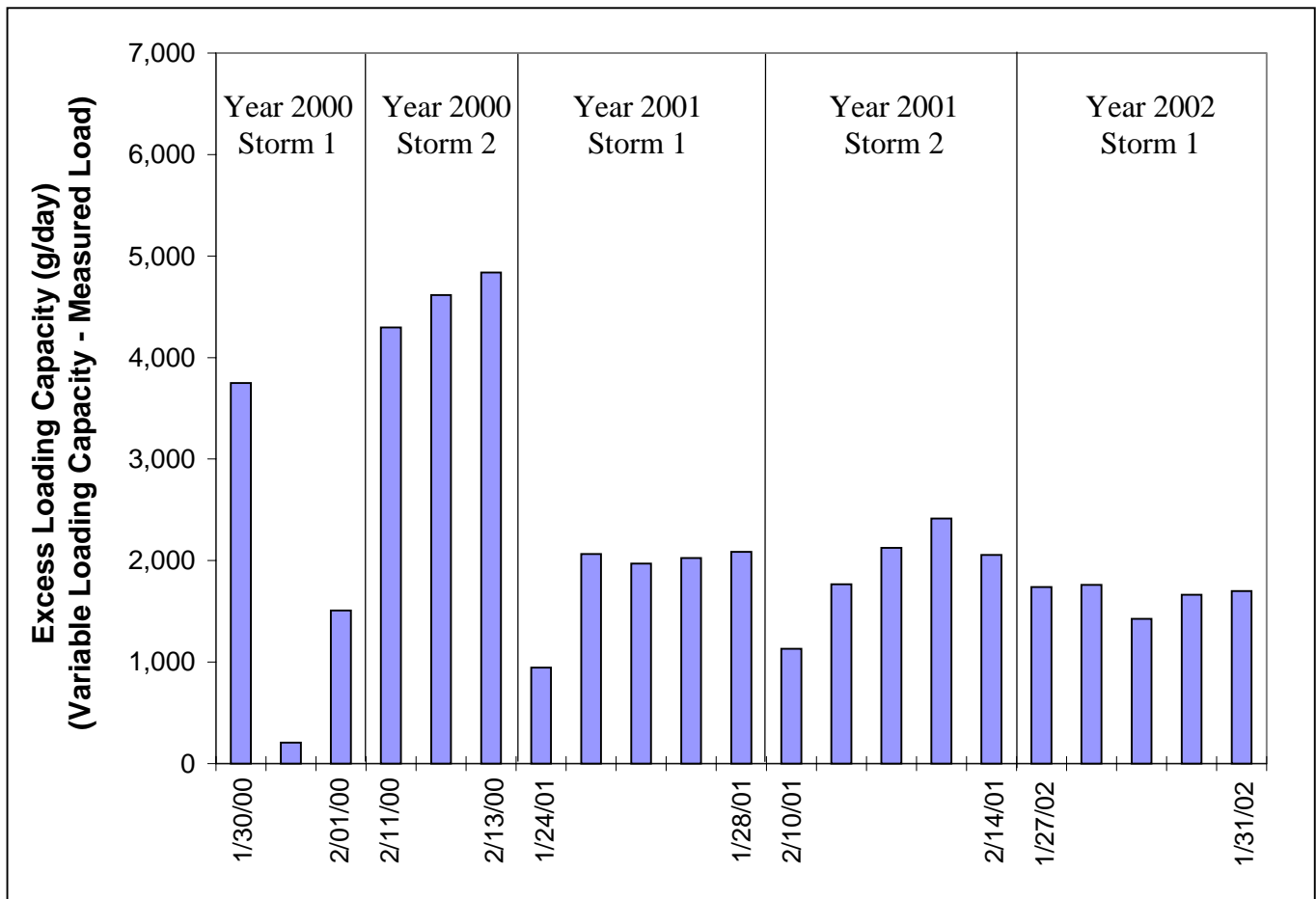


Figure A5.4. Excess Daily Loading Capacity in the Sacramento River at Colusa During Recent January and February Storms

Table A5.4. Recent Dormant Season Daily Diazinon Loads and Variable Loading Capacities for the Feather River Near Nicolaus.

	Date	Diazinon Concentration (ng/L)	Daily Average Flow (cfs)	Loading Rate* (g/day)	Variable Loading Capacity** (g/day)
Year 2000, Storm #1 (1/30 - 2/3)	1/30/00	37.5	5768	529	1129
	1/31/00	129.5	6778	2147	1327
	2/1/00	49.5	5506	667	1078
	2/2/00	53	4385	569	858
	2/3/00	43	4339	456	849
Year 2000, Storm #2 (2/11 - 2/15)	2/11/00	65	5892	937	1153
	2/12/00	35	12527	1073	2452
	2/13/00	59	17302	2497	3386
	2/14/00	30	40778	2943	7981
	2/15/00	36	20443	1800	4001
Year 2000, Storm #3 (2/21 - 2/25)	2/21/00	8	19049	373	3728
	2/22/00	9	20495	451	4011
	2/23/00	9	29875	658	5847
	2/24/00	13	24541	780	4803
	2/25/00	18	22867	1007	4476
Year 2001, Storm #1 (1/24 - 1/28)	1/24/01	27.5	3211	216	628
	1/25/01	11.67	3153	90	617
	1/26/01	24	3422	201	670
	1/27/01	16.67	3218	131	630
	1/28/01	9.5	3045	71	596
Year 2001, Storm #2 (2/10 - 2/14)	2/10/01	11.67	3026	86	592
	2/11/01	11	3733	100	731
	2/12/01	11.5	3497	98	684
	2/13/01	11.5	3162	89	619
	2/14/01	17	2959	123	579

* Daily diazinon loads are calculated using equation A1.

** Variable loading capacities are calculated using equation A3.

**Table A5.4 (Continued). Recent Dormant Season Daily
Diazinon Loads and Variable Loading Capacities
for the Feather River Near Nicolaus.**

	Date	Diazinon Concentration (ng/L)	Daily Average Flow (cfs)	Loading Rate* (g/day)	Variable Loading Capacity** (g/day)
Year 2002, Storm #1 (1/27 - 1/31)	1/27/02	47	4387	504	859
	1/28/02	38	3994	371	782
	1/29/02	28	3957	271	774
	1/30/02	25	3903	239	764
	1/31/02	16	3836	150	751
Year 2003, Storm #1 (1/11 - 1/15)	1/11/03	12	5240	154	1026
	1/12/03	10	4640	114	908
	1/13/03	9	4810	106	941
	1/14/03	10	5480	134	1073
	1/15/03	8	3620	71	709
Year 2003, Storm #2 (2/13 - 2/24)	2/13/03	22	9480	510	1855
	2/14/03	14	11400	390	2231
	2/15/03	9	11300	249	2212
	2/16/03	7	11400	195	2231
	2/17/03	14	13200	452	2584
	2/18/03	13	11500	366	2251
	2/19/03	8	11400	223	2231
	2/20/03	9	12400	273	2427
	2/21/03	7	12100	207	2368
	2/22/03	6 interpolated	11900	175	2329
	2/23/03	5	11700	143	2290
	2/24/03	5	11700	143	2290

* Daily diazinon loads are calculated using equation A1. Concentrations for the Sacramento River at Alamar were used to estimate the daily loads at Verona.

** Variable loading capacities are calculated using equation A3.

interpolated - the concentration value used in the loading rate calculations was estimated using linear interpolation between the previous day's and next day's concentration value

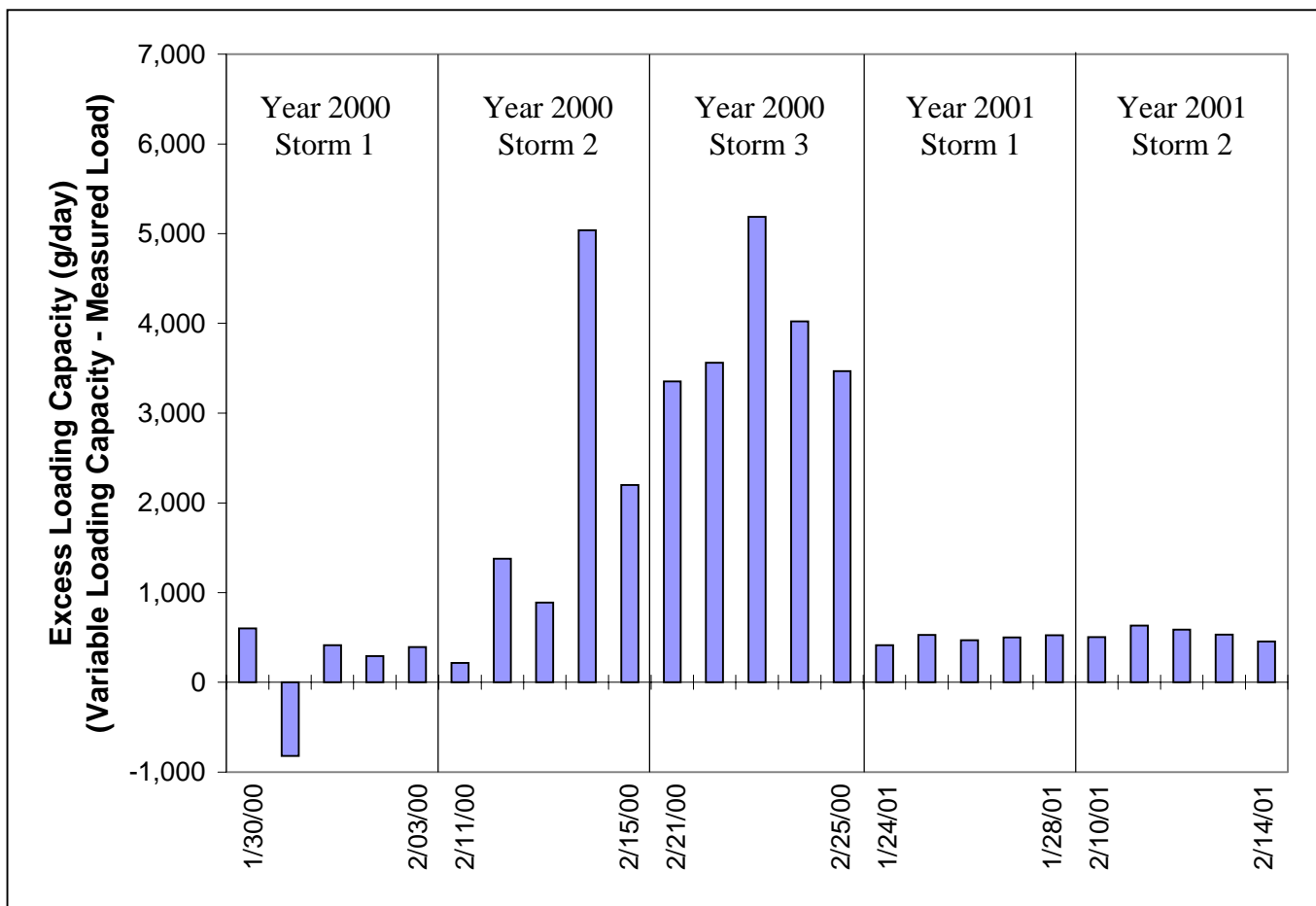


Figure A5.5. Excess Daily Loading Capacity in the Feather River near Nicolaus During Recent January and February Storms

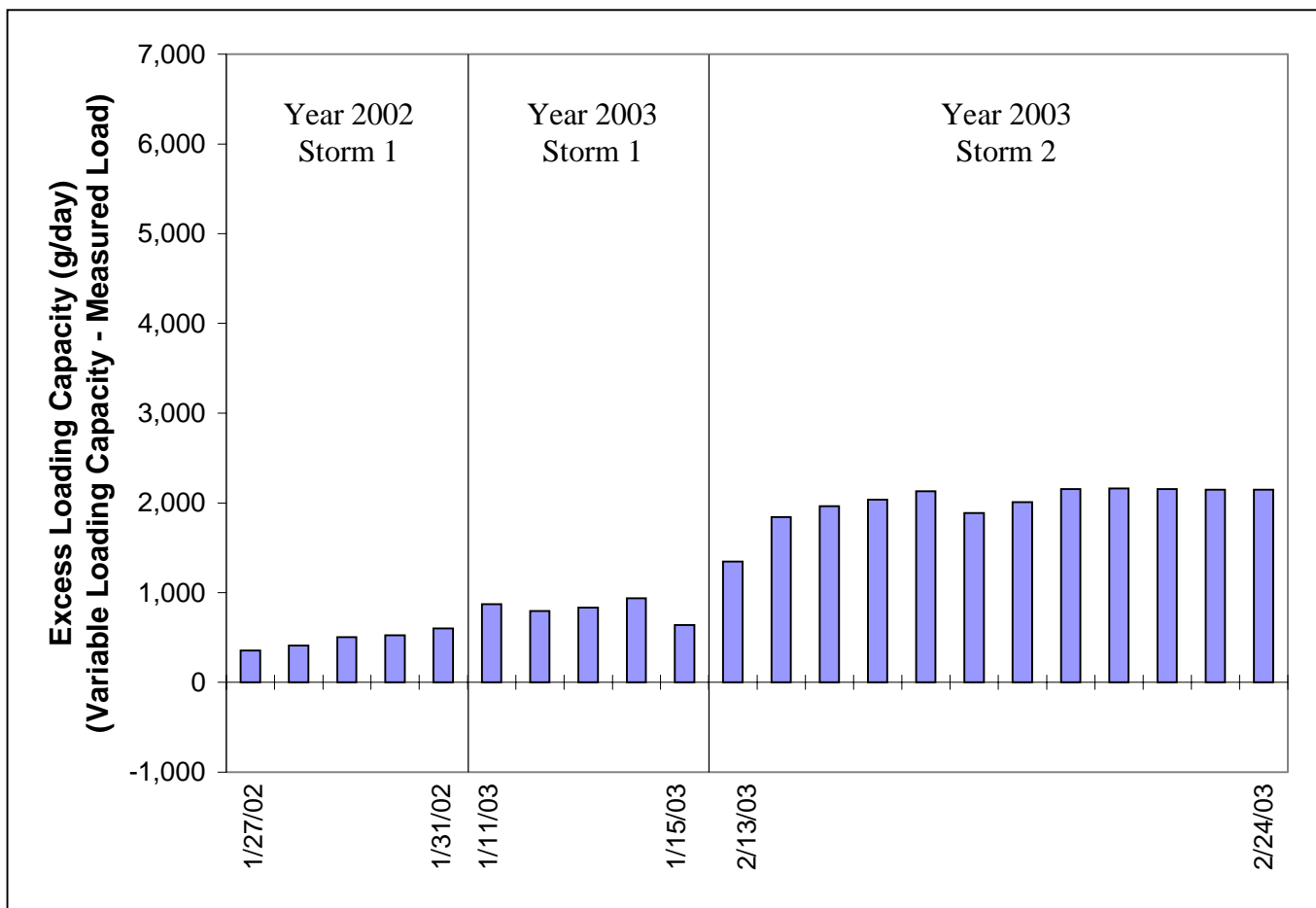


Figure A5.5 (Continued). Excess Daily Loading Capacity in the Feather River near Nicolaus During Recent January and February Storms

A.6 Allocations

The Allocations section identifies and evaluates potential distribution of the load allocations for nonpoint sources, and wasteload allocations for point sources, of diazinon in the lower Sacramento and Feather Rivers. The allocations are defined so that the sum of these allocations, along with a margin of safety, will be equal to the total loading capacity for the Sacramento River. This relationship is expressed mathematically in Equation A4.

$$\text{Equation A4: } \text{TMDL} = \text{LC} = \sum \text{LA} + \sum \text{WLA} + \text{MOS}$$

Where:

LC	=	loading capacity
LA	=	load allocations for nonpoint sources
WLA	=	wasteload allocations for point sources
MOS	=	margin of safety

A.6.1 Wasteload Allocations

The point sources with potential to discharge diazinon into the lower Sacramento or Feather Rivers or their tributaries are the municipal wastewater treatment plants and the municipal stormwater discharges in the Sacramento Valley. After the sale of non-agricultural diazinon formulations is phased out by the end of 2004, infrequent outdoor applications of diazinon may occur for several years. Diazinon may be discharged in storm water and wastewater treatment plant effluent for a few years following the phase out, so waste load allocations should be established for point source discharges. The proposed waste load allocations for point source dischargers are the diazinon water quality objectives.

A.6.2 Load Allocations

Load allocations distribute the allowable nonpoint source load among the nonpoint sources. Nearly all of the land used to grow the crops that receive approximately 99% of the agricultural diazinon applications in the Sacramento Valley in January and February (peaches, plums (dried and fresh), and almonds) are located in the four subwatersheds that are upstream of the Sacramento River at Verona (the Sacramento River above Colusa, the Colusa Basin Drain, the Sutter/Butte, and Lower Feather River subwatersheds) as shown in table 6.1. Because of its location and the fact that it has a currently operated flow gauge, the Sacramento River at Verona is an appropriate station for determining upstream load allocations.

The proposed method of determining the load allocations² for the nonpoint sources upstream of Verona is to divide the variable loading capacity at Verona (calculated using equation A3) among the four Sacramento Valley sub-watersheds that are upstream of Verona in proportion to the area in each sub-watershed that is used for growing almonds, plums (dried and fresh), and peaches. As shown in tables A4.2, A4.3 and A4.4, the average dormant season application rate for 1994 through 2001 is approximately 2 pounds of diazinon per acre for each of these three crops. Therefore, each of these crop types is weighted equally in determining the load allocations. In calculating the load allocations for the nonpoint sources upstream of Verona, eleven percent of the loading capacity at Verona is reserved for a margin of safety, as described below. The acres of these three crops in each sub-watershed and the proportional load allocations are shown in Table A6.2.

Table A6.1 Acres of Almonds, Peaches, and Plums (dried and fresh) in the Six Sacramento Valley Subwatersheds³

	Sub-watershed						
	American River	Above Colusa	Sutter/Butte Basin	Colusa Basin Drain	Lower Feather River	Cross Canal	Total
Almond Acres	230	44,607	32,882	36,798	2,047	105	116,669
Peach Acres	26	114	13,493	127	7,897	202	21,859
Plum (Dried and Fresh) Acres	86	24,247	36,526	6,627	19,129	1,323	87,938
Total area in Almonds, Peaches and Plums (acres)	342	68,968	82,901	43,552	29,073	1,630	226,466
Percent of the Total Area in the Sacramento Valley in Almonds, Peaches and Plums	0.2%	30.5%	36.6%	19.2%	12.8%	0.7%	100%

² Previous drafts of this TMDL report (Karkoski et al., 2003 – Appendix A, McClure et al., 2002) contained a discussion of five other alternatives for determining the load allocations. This appendix provides detail on the basis for the recommendations in the current Staff Report. The rationale for the selection of the proposed method of determining the loading allocations is contained in the Staff Report.

³ The acreage in each sub-watershed that is devoted to each of these land uses was determined using DWR land use data (DWR, 2001a).

Table A6.2. Load Allocations for the Four Sacramento Valley Sub-Watersheds Upstream of Verona

	Sub-watershed					
	Above Colusa	Sutter/Butte Basin	Colusa Basin Drain	Lower Feather River	Margin of Safety	Total
Almond Acres	44,607	32,882	36,798	2,047		116,335
Peach Acres	114	13,493	127	7,897		21,631
Plum (Dried and Fresh) Acres	24,247	36,526	6,627	19,129		86,529
Total Area in Almonds, Peaches and Plums (acres)	68,968	82,901	43,552	29,073		224,494
Percent of Total area above Verona in Almonds, Peaches and Plums	30.7%	36.9%	19.4%	13.0%		100%
Allocation of Acute or Chronic Variable Loading Capacity (LC _v) ⁽¹⁾ Defined by Equation A3	0.307 * (0.89 LC _v) ⁽²⁾	0.369 * (0.89 LC _v)	0.194 * (0.89 LC _v)	0.13 * (0.89 LC _v) ⁽³⁾	0.11 LC _v	LC _v
<p>(1) $LC_v = 1\text{-day or 4-day variable loading capacity as defined by equation 3: } LC_v = C_{wqc} * Q * f$ Where: LC_v = variable loading capacity, grams per day or 4-day average of grams per day; Q = flow (1-day or 4-day average), cfs; C_{wqc} = numeric target concentration for diazinon, ng/L (1-day or 4-day average); and f = unit conversion factor, 0.002446.</p> <p>(2) As described below, the allowable load for the Sacramento River above Colusa is the lesser of either: 1) the load allocation for this sub-watershed defined in the table above; or, 2) the loading capacity for the Sacramento River at Colusa defined by Equation A3.</p> <p>(3) As described below, the allowable load for the lower Feather River is the lesser of either: 1) the load allocation for this sub-watershed defined in the table above; or, 2) the variable loading capacity for the lower Feather River defined by Equation A3.</p>						

In order to meet the numeric targets in the Sacramento River above Colusa and in the lower Feather River, the loading capacities defined for the Sacramento River at Colusa and the Feather River near its outlet should not be exceeded. Similarly, to meet the numeric targets downstream in the Sacramento River at Verona and at Sacramento, the sum of the load allocations for the four subwatersheds tributary to the Sacramento River at Verona cannot be greater than the loading capacity at Verona.

Therefore, for the Sacramento River at Colusa site, the allowable load is the lesser of either: 1) the load allocation for the Sacramento River above Colusa based on the

allocation of total loading capacity for the lower Sacramento at Verona; or, 2) the loading capacity for the Sacramento River at Colusa defined in Section A.5.

Similarly, for the Feather River near Nicolaus, the allowable load is the lesser of either: 1) the load allocation for the lower Feather River watershed based on the allocation of the loading capacity for the Sacramento River at Verona; or, 2) the loading capacity for the Feather River near its outlet.

Based on historical flow data⁴, the load allocations for the Sacramento River at Colusa would be expected to exceed the acute (daily) loading capacity approximately 0.4 % of the time. Likewise the load allocation for the Sacramento River at Colusa would be expected to exceed the chronic (4-day average) loading capacity approximately 0.1% of the time. Therefore, approximately 0.4% of the time and 0.1% of the time, the allowable daily and 4-day average loads for the Sacramento River at Colusa would be defined by the acute and chronic variable loading capacities, respectively, at this site. In other words, over 99% of the time, the allowable load for the Sacramento River at Colusa would be determined by the load allocation.

Based on historical flow data⁵, the load allocations for the Feather River near its outlet would be expected to exceed the acute (daily) loading capacity less than 2% of the time. Likewise, the load allocation for the Feather River near its outlet would be expected to exceed the chronic (4-day average) variable loading capacity approximately 1% of the time. Therefore, approximately 2% and 1% of the time the allowable daily and 4-day average loads for the Feather River its outlet will be defined by the acute and chronic variable loading capacities, respectively, at this site. In other words, over 98% of the time, the allowable load for the Feather River near its outlet would be determined by the load allocation.

The flow of the Sacramento River between Verona and Sacramento is augmented by the flows of the American River, the Natomas East Main Drain, and a number of smaller drains. The load allocations for the nonpoint source discharges to the Sacramento River between Verona and Sacramento can be determined by: calculating the loading capacity for the Sacramento River at Sacramento; subtracting the loading capacity for the Sacramento River at Verona (since it has already been allocated to nonpoint sources upstream of Verona) and subtracting a 30 percent margin of safety, described below. This method of determining the load allocations for the nonpoint source discharges to the Sacramento River between Verona and Sacramento can be described using equation A5.

Equation A5: $LA_{vs} = 0.70 (LC_{ver} - LCs)$

Where:

⁴ Flow data from January 1951 through September 2000

⁵ Flow data from January 1969 through September 2000

LAVs = load allocation for the nonpoint source discharges to the Sacramento River between Verona and Sacramento, in grams per day or 4-day average of grams per day.

LCver = loading capacity calculated at Verona using equation A3, in grams per day or 4-day average of grams per day.

LCsac = loading capacity calculated at Sacramento using equation A3, in grams per day or 4-day average of grams per day.

A.6.3 Margin of Safety and Seasonal Variation

The load allocations for this TMDL are determined by arithmetically dividing up the loading capacity among the significant sources. This methodology assumes no significant reductions in diazinon loading due to degradation or removal from the water column by adsorption to sediment particles and subsequent sediment deposition. In addition to this conservative assumption an explicit margin of safety is included in the calculation of the load allocations for this TMDL, in order to provide assurance that when the load allocations described below are met, the numeric targets are also met.

The total loading capacity for the Sacramento River at Verona is based upon the daily flow in the river at Verona. The flow gauge at Verona is maintained by the USGS, who rate the flow measurements at this station as accurate to within 10% of the actual daily discharge (Markham, 1996). Since daily flow and loading capacity are directly proportional, the margin of safety for the Sacramento River at Verona, 10% of the loading capacity for the Sacramento River is included in the margin of safety applied at the Sacramento River at Verona. An additional one percent margin of safety is added to account for the minor amount of orchard acreage in the Cross Canal sub-watershed (shown in Table A6.1) that is upstream of the Sacramento River at Verona, and the minor amount of Loading Capacity used by NPDES sources upstream of Verona. The explicit margin of safety applied to the Sacramento River at Verona is 11% of the total Loading Capacity for the Sacramento River at Verona.

Thirty percent of the land area tributary to the Sacramento River between Verona and Sacramento are urban lands⁶. The urban land areas generally fall under NPDES permits and are subject to the waste load allocations, which are equivalent to the diazinon water quality objectives. When releases from upstream reservoirs such as Folsom are considered, less than 30% of the flows into this reach of the Sacramento River are likely runoff from urban areas or wastewater treatment plant effluents. An explicit margin of safety of 30% is therefore applied to the available loading capacity between of the Sacramento River between Verona and Sacramento. This margin of safety accounts for the potential assimilative capacity used up by the wasteload allocations for runoff from urban land areas and wastewater treatment plant effluents that discharge into this reach of the Sacramento River.

⁶ Urban land use data from DWR, 2001a.

There is also an implicit margin of safety in the use of the variable loading capacity. The variable loading capacity does not allow for any exceedances of the criteria maximum concentrations, while the proposed water quality objectives allow exceedances of the criteria maximum concentrations as frequent as once every three years. Since the variable loading capacity varies with flow, seasonal variations and critical conditions are explicitly considered in determining the variable loading capacity.

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